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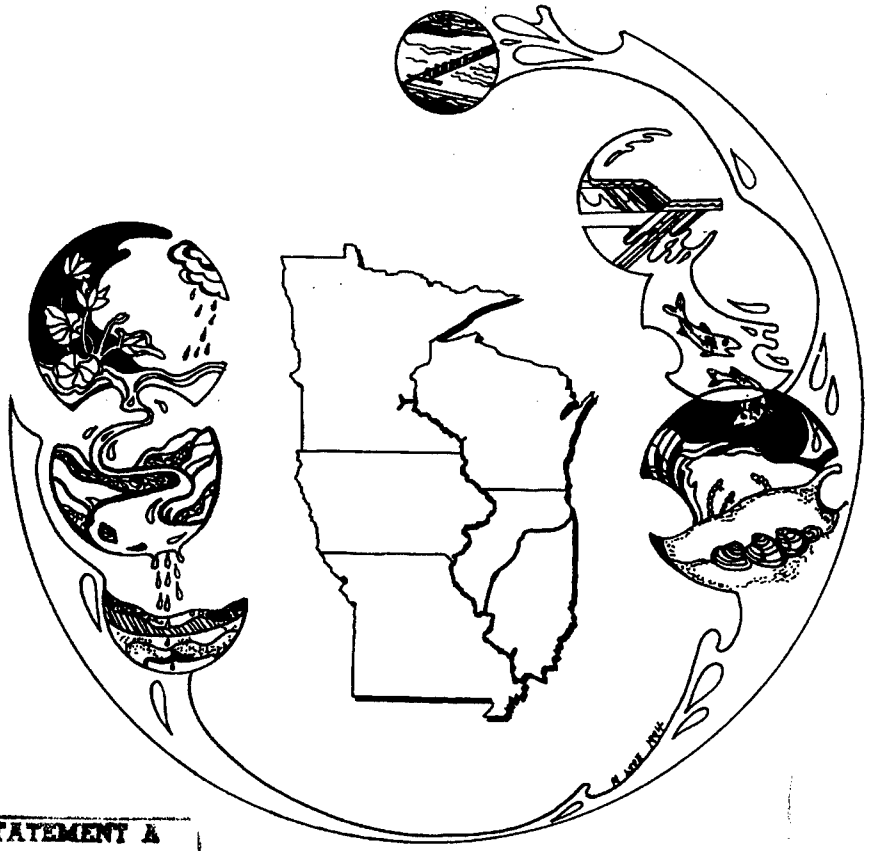
A Comprehensive Evaluation of Three Mussel Beds in Reach 15 of the Upper Mississippi River



October 1997

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A Comprehensive Evaluation of Three Mussel Beds in Reach 15 of the Upper Mississippi River

by

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Preface

This report originally was submitted to the Illinois Department of Natural Resources and is being provided in this format as a service to Long Term Resource Monitoring Program (LTRMP) partners.

LTRMP interests in the subject matter of this report are embodied in the LTRMP Operating Plan[1] in Strategy 2.2.7, *Monitor and Evaluate Selected Macroinvertebrate Populations and Communities*. This report was developed with funding provided by the former Illinois Department of Conservation (contract number PC 955391) which was reorganized into the Illinois Department of Natural Resources effective July 1, 1995. Additional support was provided by the Illinois Natural History Survey and the Upper Mississippi River System Long Term Resource Monitoring Program, a cooperative effort of the U.S. Army Corps of Engineers, National Biological Service, and natural resource agencies of Illinois, Iowa, Minnesota, Missouri, and Wisconsin.

The LTRMP is being implemented by the Environmental Management Technical Center, a U.S. Geological Survey science center, in cooperation with the five Upper Mississippi River System (UMRS) States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin. The U.S. Army Corps of Engineers provides guidance and has overall Program responsibility. The mode of operation and respective roles of the agencies are outlined in a 1988 Memorandum of Agreement.

The UMRS encompasses the commercially navigable reaches of the Upper Mississippi River, as well as the Illinois River and navigable portions of the Kaskaskia, Black, St. Croix, and Minnesota Rivers. Congress has declared the UMRS to be both a nationally significant ecosystem and a nationally significant commercial navigation system. The mission of the LTRMP is to provide decision makers with information for maintaining the UMRS as a sustainable large river ecosystem given its multiple-use character. The long-term goals of the Program are to understand the system, determine resource trends and effects, develop management alternatives, manage information, and develop useful products.

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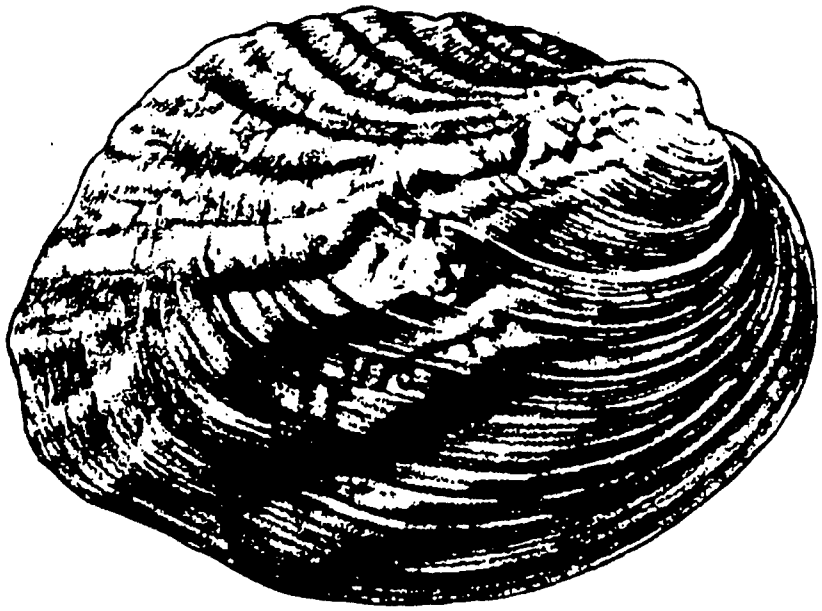
[1]U.S. Fish and Wildlife Service. 1993. Operating Plan for the Upper Mississippi River System Long Term Resource Monitoring Program. Environmental Management Technical Center, Onalaska, Wisconsin, Revised September 1993. EMTC 91-P002R. 179 pp. (NTIS #PB94-160199)

Illinois Natural History Survey

A comprehensive evaluation of three mussel beds in Reach 15 of the Upper Mississippi River



Center for Aquatic Ecology

Scott D. Whitney, K. Douglas Blodgett, and Richard E. Sparks

Illinois Natural History Survey
August 1996

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Disclaimer

The findings, conclusions, and views expressed herein are those of the researchers and are not necessarily the position of the Illinois Natural History Survey or the Illinois Department of Natural Resources.

Use of the term "Reach"

Terms are important, because they determine our perception of the thing that is being described. Use of the term "pool" perpetuates a misconception among readers and reviewers outside the upper Mississippi Basin that there is little of the natural river left. Readers assume that we are talking about "a deep, still place in a stream or river" where the water is standing more than it is flowing. "Pool" is often associated with "stagnant". Many readers and reviewers outside the Mississippi Basin have the misconception that the river is a polluted barge canal, or a series of large reservoirs. Some reviewers assume the river is altered that nothing about the structure and function of ecosystems could be learned by studying it; i.e. they considered it as man-made as an agricultural field, boat harbor, canal, or storage reservoir. Use of the word "pool" for any portion of the Mississippi is misleading, because "pool" commonly refers to small bodies of water (e.g., "puddles"). However, the term has been used by the U.S. Army Corps of Engineers since at least the 1930's, when the 9-foot channel and associated navigation dams were constructed. The term "reach" is much more appropriate for the stretch of river between navigation dams or between bends in the river; indeed these are two of the standard definitions and common usage for "reach". "Pool should be a subset of "reach", because navigation dams create wide deep places in the river only part of the distance upstream to the next dam. In addition, some navigation reaches, such as Reach 15, are swift channels with scarcely any slackwater "pool" at all. Following are definitions of the two terms:

Definitions of Pool and Reach

Stein, Jess, and Laurence Urdang (eds.). 1971. The Random House dictionary of the English language. Random House. New York. 2059pp.

Pool	Reach
1. A small body of standing water: pond.	**24.** A continuous stretch or extent of something: a *reach of woodland.*
2. A puddle.	**25.** Also called **pound**, a level portion of a canal between locks.
3. Any small collection of liquid on a surface.	**28.** a straight portion of a river between two bends.
4. A still, deep place in a stream.	

Brown, Lesley (ed.). 1993. the new shorter Oxford English dictionary on historical principles. Vol. 2, N - Z. Clarendon Press, Oxford. 3801pp.

Pool	Reach
1a. A small body of standing or still water, *especially* one of natural formation. Old English. **b.** A small shallow accumulation of any liquid; a puddle.	**1a.** An enclosed stretch of water; a bay. Long obsolete, except in Canadian dialect. **b.** A portion of a river, channel, or lake between two bends; a portion of a canal between two locks.
2. A deep still place in a river or stream.	**2.** *General.* A continuous stretch, course, or extent in space or time.
4. A tank or other artificially constructed receptacle (to be) filled with water for swimming, diving, etc.	

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Executive Summary

Unionid mussels were collected by quadrat sampling at three sites in Reach 15 of the Upper Mississippi River between July 1994 and September 1995: Sylvan Slough (rivermile (RM) 485.8) within a mussel refuge (commercially unharvested since 1988); Case-IH (RM 488.5) (commercially harvested); and Illiniwek (RM 492.4) (commercially harvested). A total of 7,107 mussels were collected representing 26 species, including one federally endangered species (*Lampsilis higginsi*), two state endangered species (*Plethobasus cyphyus* and *Cumberlandia monodonta*), and one state threatened species (*Ellipsaria lineolata*). Illiniwek had the greatest mussel diversity and abundance with 25 species and a mean density of 118.3/m^2, followed by Case-IH with 23 species and 86.7/m^2, and Sylvan Slough with 20 species and 53.4/m^2. Temporal trends in unionid abundance (1985-95) reflect significant declines ($p \leq 0.001$) in overall unionid densities as well as densities for individual species at both Sylvan Slough, where mean unionid density declined from 100.1/m^2 in 1985 to 53.4/m^2 in 1994-95 with 6 species showing significant declines, and Case-IH where mean unionid density declined from 139.2/m^2 in 1985 to 89.8/m^2 in 1994 with 4 species showing significant declines. The four mussel species which dominated our collections were *Truncilla truncata*, *Ellipsaria lineolata*, *Quadrula pustulosa*, and *Amblema plicata*. Recent recruitment estimates for the ten most common species indicate a high degree of variability among species and study sites. Some species, such as *Megalonaias nervosa*, exhibited very low recruitment densities (0.00 to 0.03/m^2), while others like *Quadrula pustulosa* exhibited good recruitment densities (3.7 to 4.3/m^2). Temporal trends in recruitment evaluated by recent recruitment densities and size-frequency histograms demonstrate the unpredictable nature of unionid recruitment; some species (i.e., *A. plicata* and *Q. pustulosa*) were fairly consistent, recruiting young individuals to their populations each year, while other species (i.e., *M. nervosa* and *Q. metanevra*) were more sporadic, recruiting young to their populations only once or twice within a ten-year period. On average, commercial mussel species (*A. plicata*, *M. nervosa*, *Q. pustulosa*, *Q. metanevra*, and *Q. quadrula*) reached sexual maturity during their seventh or eighth year, with a range from 5 to 12 years of age. The time required for a commercial species to reach minimum harvestable size ranged from 19 to 24 years; *M. nervosa* took the longest, requiring 24 years to reach a shell height of 101.60 mm (4 inch), *A. plicata* required 21 years to reach a shell height of 69.85 mm (2.75 inch), and the three *Quadrula* species required 19 to 21 years to reach a shell height of 63.5 mm (2.5 inch).

We believe the current mussel refuges only exist on paper and subsequently do not provide the services for which they were intended. Our studies in Reach 15 suggest illegal harvest has occurred in the Sylvan Slough refuge, since all commercial species collected within the refuge demonstrate a truncated size distribution at the minimum commercial size limit, a characteristic of harvested areas. In fact, individuals have been prosecuted for harvesting mussels in Sylvan Slough and other UMR mussel refuges.

Zebra mussels (*Dreissena polymorpha*) were first established in Reach 15 during late 1991 or early 1992, but did not become abundant until 1995. Mean density at Illiniwek increased exponentially from less than 1/m^2 in July 1994 to 2,519/m^2 in July 1995. Similarly, zebra mussel infestation (% unionids with 1 or more zebra mussels) at Illiniwek increased significantly from 1% in July 1994 to 48% in September 1995. Mean and maximum degree of infestation increased from 0.00/unionid and 2/unionid in July 1994 to 2.3/unionid and 37/unionid in September 1995. Length-frequency histograms indicate that at least one and possibly two zebra mussel recruitment events occurred in Reach 15 during 1994 and 1995. These histograms also indicate that zebra mussels which settle in Reach 15 during May or June can reach 15- to 20-mm in length by the end of their first growing season (October). Although rapid increases in zebra mussel densities and infestation of unionids represent an alarming trend, we did not observe any negative zebra mussel effects on the Reach 15 unionid populations (i.e., increased mortality, siphon occlusion, etc.) during the current study. However, based on past experience in the Illinois River, we predict that by 1996 or 1997 unionid mussels in Reach 15 of the UMR will experience significantly greater infestations by zebra mussels and will subsequently suffer reduced fitness and increased mortality.

Management recommendations concerning the protection of mussel populations in Reach 15 and throughout the Upper Mississippi River (UMR) include: (1) closing the commercial harvest of live *Megalonaias nervosa*, (2) establishing entire reaches of the UMR as mussel refuges, (3) developing population models to guide and assist the management of mussels, and (4) monitoring zebra mussel densities and impacts in the Mississippi River.

Introduction

Unionid mussels are considered among the most endangered faunal groups inhabiting the United States (Shannon et al. 1993; Neves 1993). Fifty-one species of mussels occurred historically in the Upper Mississippi River (UMR)--a substantial portion (17%) of the 297 taxa of freshwater mussels found in North America (Turgeon et al. 1988). In the UMR there are currently 18 mussel species listed as threatened or endangered including three federally endangered mussel species, *Lampsilis higginsi, Potamilas capax*, and *Quadrula fragosa* (Page et al. 1991). Mussel populations in the UMR have been subject to a number of stresses, including (1) heavy commercial harvesting formerly for the production of pearl buttons and more recently to supply raw shell for the Japanese cultured pearl industry, (2) pollution from both urban centers and nonpoint sources, and (3) modification of the river for navigation (Sparks and Blodgett 1983; Sparks and Blodgett 1988). Between 1982 and 1986 massive die-offs of mussels occurred in the UMR (Neves 1987, Blodgett and Sparks 1987 a, b). Although the die-offs were investigated, the causes were never identified (Sparks et al. 1990).

In response to the widespread mussel dieoffs and increasing commercial harvest, the Illinois Department of Conservation designated seven areas in the Illinois portion of the Mississippi River as mussel refuges in July 1988 (Figure 1). The primary objectives of these refuges were to (1) protect endangered or threatened mussels, (2) provide a seed source to repopulate other areas, and (3) serve as unharvested reference areas for comparison with harvested areas. If populations in the harvested areas declined while those in the refuges maintained themselves or increased, then more stringent harvest regulations might be indicated. If populations in both areas declined, then other factors should be investigated, such as poor water or sediment quality, parasites, disease, or declines in the fishes that host and disperse the glochidia (larvae) of the mussels.

Critical information concerning the life-history parameters and population dynamics of freshwater mussels is often lacking and desperately needed for the sound management and conservation of this resource. The need is especially crucial for commercially harvested species. Current regulations governing the commercial mussel harvest (e.g., legal species, minimum shell size, or season) are based on inadequate scientific information and typically reflect preferences of the shelling industry (Thiel and Fritz 1993). Monitoring and evaluation of the resource throughout the UMR rely heavily on annual shell buyers reports. The UMR states have yet to establish uniform regulations to govern commercial mussel harvest. The current system which regulates and monitors commercial mussel harvest in the UMR is antiquated, based on inadequate scientific information, and in desperate need of review and reform. It is especially important to reevaluate current mussel regulations and conservation strategies now that zebra mussels have been found in the Mississippi River. The U.S. Fish and Wildlife Service has predicted 20 species of mussels in North America will become extinct over the next few years as a result of the zebra mussel invasion (Biggins 1992). Many difficult management decisions will likely be made in the coming years in attempts to preserve and protect the remaining mussel resource. Without reliable scientific information, management decisions may be ineffective or even cause further harm to mussel populations.

The objectives of the comprehensive evaluation of Reach 15 mussel beds were to assess the status of harvested and unharvested (refuge) mussel beds by evaluating the following parameters: (1) species abundance and richness, (2) recruitment, (3) age and growth, (4) mortality, and (5) status and impacts of newly introduced zebra mussels. Long-term population trends were evaluated by comparison of results with those from previous scientific mussel surveys conducted in Reach 15.

Methods

Study Sites

During 1994 and 1995, we quantitatively sampled three mussel beds in Reach 15 of the UMR near Moline, Illinois (Figure 2). One mussel bed, Sylvan Slough (rivermile [RM] 485.8), was located within a mussel refuge established in 1988; harvesting mussels in the refuge is illegal. Two mussel beds, Case-IH (RM 488.5) and Illiniwek (RM 492.4), are known to be commercially harvested (Figure 2). A more detailed description and location of each study site follows.

(1) Sylvan Slough (RM 485.8): (Figure 3) - This site was chosen as a reference or unharvested site. It was designated as one of the seven mussel refuges in July 1988 (Figure 1). Quantitative mussel collections were made at this site during 1983, 1985, and 1987 by the Illinois Natural History Survey (Sparks and Blodgett 1983, Blodgett and Sparks 1987a and 1987b). These previous surveys reported an abundant mussels population

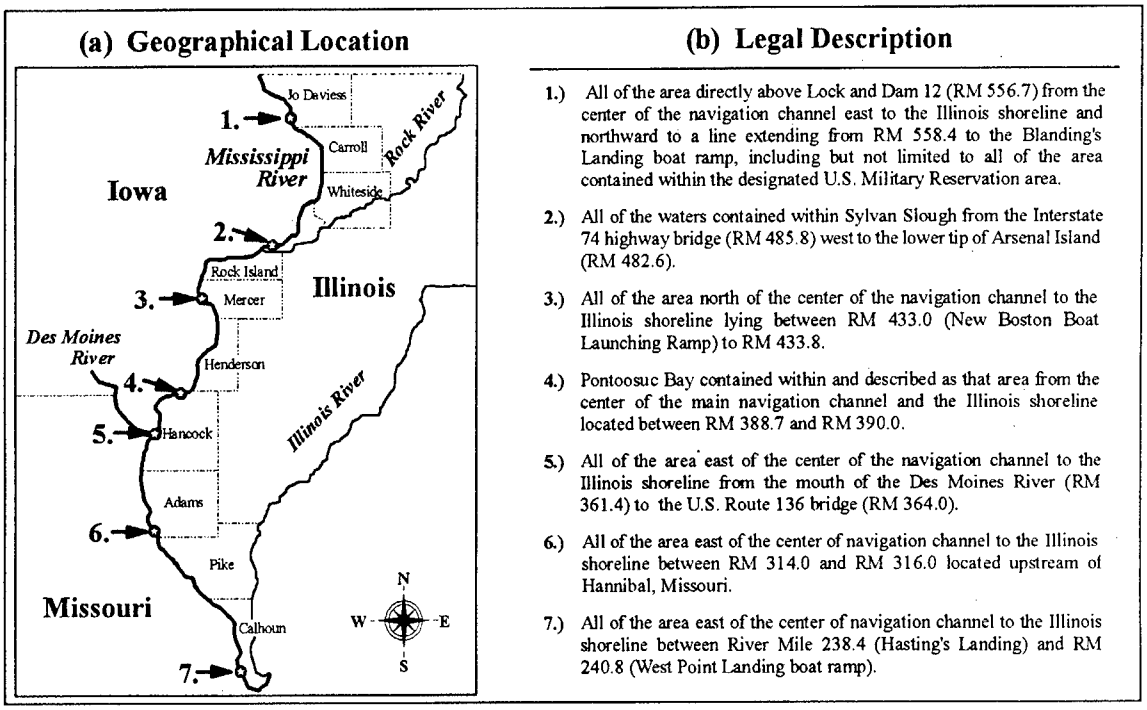

Figure 1. Upper Mississippi River mussel refuges (a) geographical location and (b) legal description.

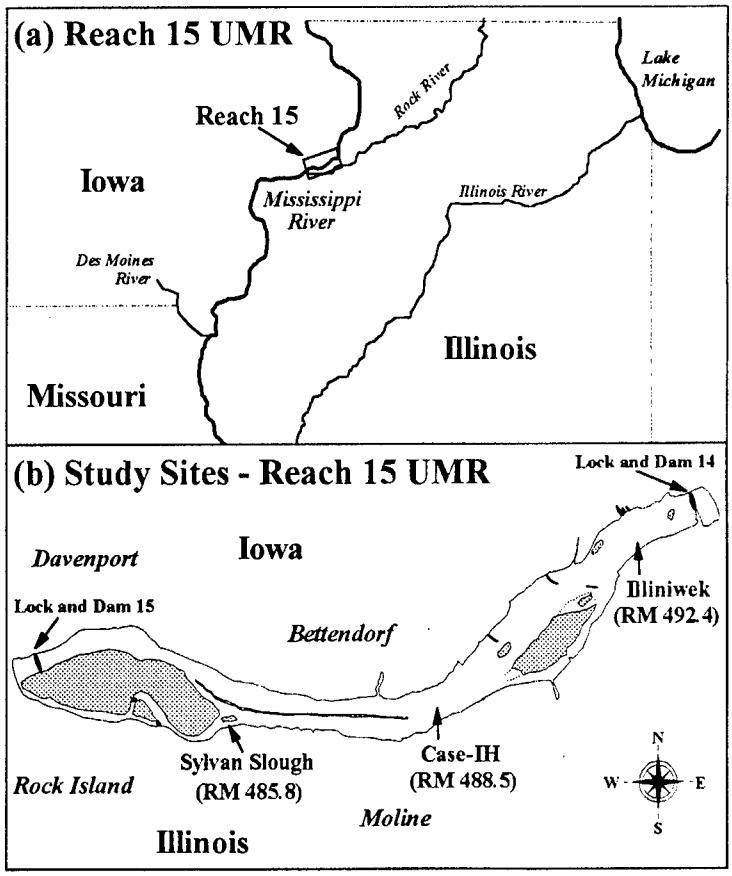

Figure 2. Location of (a) Reach 15 in the Upper Mississippi River (UMR) and (b) enlarged view of Reach 15 to show study sites where quantitative mussel samples were collected, 1994-95.

with a rich species assemblage including the federally endangered *Lampsilis higginsi*.

During the present survey quantitative samples were collected on three separate occasions at the upriver end of Sylvan Slough between the Interstate-74 highway bridge and the upriver tip of Arsenal Island (Figure 3, Table A-1). The location for each collection period differed slightly to prevent sampling on the same spot more than once. Substrate consisted primarily of sand/silt with small rock cobble and water depths ranged from 2 to 4 m (6 to 10 ft). During our sample collections we noted extensive use of this area by recreation watercraft; on weekends as many as fifteen boats were observed floating or anchored within this small area of Sylvan Slough.

(2) Case-IH (RM 488.5) : (Figure 4) - This site was chosen as a commercially harvested bed. Interviews with commercial musselors indicated this bed had been extensively harvested in the 1970's but has received only occasional commercial pressure in the past ten years. We observed two commercial mussel boats operating in this area during our summer 1994 collections. Quantitative mussel collections were made at this site in 1985 and 1987 by the INHS (Blodgett and Sparks 1987a and 1987b). These previous surveys reported mussels exceptionally abundant, the number of species exceptionally rich, and the federally endangered *Lampsilis higginsi* present.

Quantitative samples were collected at this site in July and August 1994 (Table A-1). The collection area was adjacent to the main channel and 150 m out from the Illinois shoreline. Triangulation to the site was accomplished using a cement piling, boat ramp, and cement water tower (Case-IH logo on side). The site was located on a straight line between the boat ramp and middle cement piling and directly out from the cement water tower. The substrate consisted of extensive areas of bedrock with intermittent areas of sand and rock cobble. Water depths within the sampling area ranged from 4 to 6 m (12 to 20 ft.).

(3) Illiniwek: RM 492.4 (Figure 5) - This site was also chosen as a commercially harvested bed. According to local musselors, this particular area (1) had been one of the more productive beds in Reach 15 in the late 1960's and early 1970's, but was depleted of commercial-size shells during the late 1970's or early 1980's, (2) was no longer of commercial importance and most experienced musselors had moved on to more profitable beds, and (3) occasional inexperienced musselors had been observed working this area periodically in the past ten years. To our knowledge, this site has not been scientifically delineated or quantitatively sampled previously.

Quantitative samples were collected on four occasions: June and August of 1994 and June and September of 1995. In addition, 415 mussels were collected qualitatively at this site on 1 December 1994 for use in sediment toxicity tests (Stoekel et al. 1996). The collection area was located approximately 1 rivermile downriver from Lock and Dam 14 and from 30 to 50 m offshore from Illiniwek State Park. Substrate was fairly uniform, consisting primarily of sand with occasional small rock cobble. Water depths ranged from 2 to 3 m (5 to 9 feet).

Field procedures

During four sampling periods between July 1994 and September 1995 we collected from 72 to 116 quantitative samples representing a total surface area of 18 to 34 m^2 at each of the three sites in Reach 15 (Table A-1). Quantitative samples were collected using procedures normally employed by the INHS River Research Lab (Sparks and Blodgett 1983, Blodgett and Sparks 1987a & 1987b). Biologists using surface supplied diving techniques removed all material from within 0.25-m^2 or 1-m^2 metal frames to a depth of 18 cm. Quantitative samples were collected by either the **transect method**, where the diver places a metal frame at 5-m intervals along a 100-m transect line anchored to the substrate, or by **random placement**, where the diver places a metal frame at random intervals while moving upriver. Samples were sent to the surface in separate nylon mesh bags and rinsed with river water through a series of four sieve trays (mesh apertures of 20, 10, 5, and 2 mm). Material retained by each tray was carefully examined to remove live and recently dead mussels. Mussels were classified as recently dead using the following criteria: (1) if soft parts were present, unable to close valves when prodded; (2) if soft parts were absent, the periostracum was intact, valves were firmly joined by the hinge ligament, and the interior nacre was shiny and not the least bit chalky. Live and recently dead mussels were identified to species (Cummings and Mayer 1992) and morphological shell measurements of length, width, and height (Stansbery 1961) were recorded to the nearest 0.01 mm using digital calipers. Most of the mussels collected were returned to the river; however, a subsample of at least 30 individuals of the most common species was retained and frozen for further analysis. Zebra mussels attached to unionids were individually counted and measured (shell length).

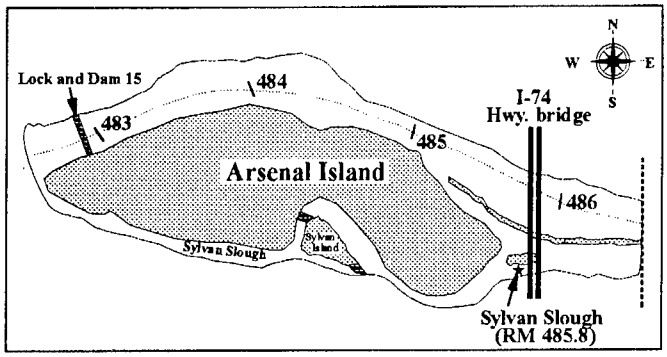

Figure 3. Location of Sylvan Slough study site (RM 485.8) in Reach 15 of the Upper Mississippi River.

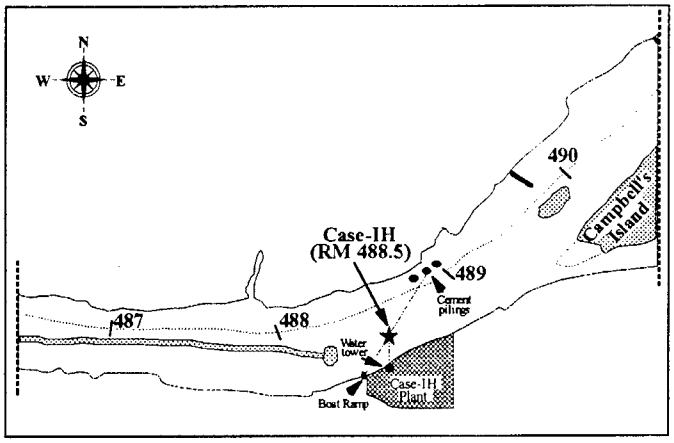

Figure 4. Location of Case-IH study site (RM 488.5) in Reach 15 of the Upper Mississippi River.

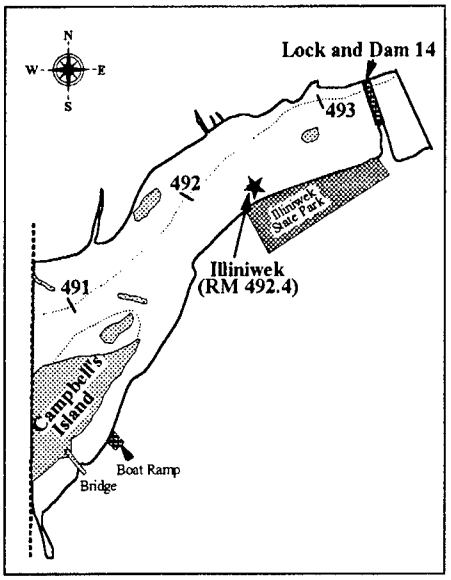

Figure 5. Location of Illiniwek study site (RM 492.4) in Reach 15 of the Upper Mississippi River.

Laboratory procedures

Laboratory processing included both weight and age determination of individual mussels from selected species (Table 1). Frozen mussels were rinsed in warm water to remove ice from the exterior of the shell then weighed to the nearest 0.01 g (live weight). Next the mussel was forced open with a scalpel and soft tissue was removed; we determined wet weights for both tissue and shell. They were dried at 105°C to a constant weight and re-weighed to determine dry weights. Shells will be archived in Illinois Natural History Survey's mussel collection at the University of Illinois - Urbana/Champaign.

The estimated age of an individual mussel was determined by counting growth bands on the external surface of the shell (Chamberlain 1931, Stansbery 1961) and within thin radial cross sections of the shell and hinge ligament (McCuaig and Green 1983, Neves and Moyer 1988). In 1994, from 10% to 30% of each of the following commercially harvested species were aged using both techniques: *Amblema plicata*, *Megalonaias nervosa*, *Quadrula pustulosa*, *Quadrula quadrula*, and *Quadrula metanevra*. The two methods of age analysis yielded comparable results (± 1 year); however, preparation of thin radial cross sections was very time consuming, requiring from 20 to 30 minutes per mussel compared with 1 to 2 minutes per mussel for external counts. Therefore, only external ring counts were used to age mussels collected in 1995.

The age at which an individual mussel became sexually mature was estimated by recording the age at which a marked decrease in distance between external growth bands occurred on the external shell surface of adult mussels (Stansbery 1961, Stein 1973). This technique was performed after shells and tissue had been separated and dried, therefore, we were unable to validate this method by examination of the gonads for maturity and ripeness. The age of sexual maturity was determined from a subsample of randomly selected shells of adult mussels of the five commercial species, *A. plicata* (n=78), *M. nervosa* (n=29), *Q. metanevra* (n=12), *Q. pustulosa* (n=38), and *Q. quadrula* (n=28). The mean, standard deviation, and range of sexual maturity age(s) were calculated for each species.

Data Analysis

Data recorded in the field and laboratory during 1994-95 was analyzed in accordance with the five primary objectives of the study: (1) species abundance and richness, (2) recruitment, (3) age and growth, (4) mortality, (5) status and impacts of newly introduced zebra mussels. In addition to the information collected in the present survey, we also analyzed data collected from three previous quantitative surveys at the Sylvan Slough and Case-IH sites (Sparks and Blodgett 1983, Blodgett and Sparks 1987a and 1987b) to identify temporal trends in these mussel populations. We also reviewed two mussel survey reports from Sylvan Slough conducted by private consultants within the past decade (Stanley Consultants, Inc. 1993, Cawley 1989). Annual commercial harvest reports from Illinois, since 1963 (Fritz 1988, Williamson 1995) and Iowa since 1984 (Ackerman and DeCook 1995) were used to evaluate the effects of long-term commercial harvest on mussel populations in Reach 15.

Species richness and abundance

Species richness was determined by tabulating the total number of species collected from quantitative sampling at each of the study sites. Abundance, typically referred to as density (number of individuals/m^2), was determined for each quantitative sample; data from all quantitative samples collected at each site from July 1994 through September 1995, were averaged to determine overall unionid and species specific density means. Statistical comparison of density means among and within the three study sites was conducted using an extended t-test designed for comparisons of means obtained from unequal sample sizes. Statistically significant difference between means was determined at the $p \leq 0.05$ level.

Mean densities were used to classify each unionid species as **very abundant** (> 20.01/m^2), **abundant** (10.01 to 20.00/m^2), **common** (1.01 to 10.00/m^2), **uncommon** (0.34 to 1.00/m^2), or **rare** (< 0.33/m^2) (Table A-5). This arbitrary classification system was designed specifically for Reach 15 mussel populations to categorize species with similar abundance; it may or may not apply to other reaches of the Mississippi River.

Using a technique described in Green (1979) we computed the number of samples required to estimate unionid density within 10%, 20%, 30%, 40%, and 50 % of the actual density with a 0.05% probability of being incorrect using the following equation: $\mathbf{n = [(2SD) \div (xM)]^2}$, where, n = number of samples required, SD = standard deviation, x = desired level of accuracy (i.e., 10% = 0.1), and M = mean unionid density based on samples collected

Density distributions based on mussel age, shell length, and shell height were used to evaluate spatial and

temporal trends in mussel populations among and within the Reach 15 study sites. Density distributions combine both mean density (no./m^2) and frequency distributions for a species within each study site (i.e., % of population by age or 5-mm size intervals). For example, the mean density for *A. plicata* at Illiniwek (RM 492.4) was 10.34/m^2 and the percent of mussels within the 60-mm shell length interval (55.01 to 60.00 mm) was 14.6%; therefore, the calculated density of this size interval is 10.34/m^2 × 0.146 = 1.51/m^2. Density distributions were presented as histograms and in tabular format, the latter allowing one to calculate the mean density of a specific age group or size range by summing the mean densities of all mussels within the desired group or range.

Recruitment

We evaluated recent recruitment for ten of the more common mussel species we collected in Reach 15 during 1994-95 (Appendix F). The size criteria to define a recent recruit was species specific and typically represented mussels less than three years of age. For most species, individuals less than 30-mm in length constituted recent recruitment. However, the size was reduced for small, short-lived species such as *Truncilla truncata* (< 15 mm), *Obliquaria reflexa* (< 15 mm), and *T. donaciformis* (< 10 mm). Length-frequency and density tables were used to determine the percentage (%) and density (no./m^2) of recent recruits within the population at each study site and for each year sampled (i.e, Sylvan Slough 1983, 1985, 1987, and 1994-95) to evaluate recruitment patterns over the past decade.

Age and Growth

The relationship between mussel age and growth was evaluated using regression plots and regression formulas. Therefore, it is crucial that the reader have a basic understanding of these two techniques. We offer the following brief explanations:

Regression plots are used to determine the degree of relationship between the independent (X) and dependent (Y) variables. Regression plots attempt to fit a line to a series of data having specific X,Y coordinates. The more closely the data points fall along the line the better the relationship. The proportion (or percentage) of the total variation in Y that is explained or accounted for by the fitted regression is termed the *coefficient of determination*, r^2, which may be thought of as a measure of the strength of the relationship.

Regression formulas are mathematical equations which describe the relationship between the X and Y variables by evaluating the *regression coefficient* or *slope* (**b**) and the *y-intercept* (**a**) of the best fit regression line (Zar 1984). Knowing the parameter estimates of *a* and *b* for the regression equation, one can calculate the value of Y (dependent variable) at a stated value of X (independent variable). The closer the r^2 value is to 1 the less variability there is in the data and therefore the more reliable the estimate of Y.

The species and number of individual mussels used in growth analysis were limited to those which we had aged or weighed in 1987 and 1994-95 (Table 1). No distinction was made regarding collection location (study sites); rather, growth analysis was based on composite mussel samples from all Reach 15 study sites. We used a stepwise procedure (Zar 1984) in selecting the regression formula which consistently provided the best fit (i.e., highest r^2) for mussel growth data.

Age-size relationships were best described by **3rd order polynomial regression** formulas ($y = a + b_1x + b_2x^2 + b_3x^3$). Mean shell measurements of each of the five commercial species (Appendix G, Part II) served as the dependent variables and mussel age as the independent variable in growth curves (regression plots). Regression formulas were used to calculate shell size (i.e., length, width, and height) at ages from 1 to 30 years. By switching the variables we derived regression formulas for each of the five commercial species to calculate age for a given shell length or shell height. Formulas based on shell length and age were used to calculate the age of all mussels which had not been aged.

Size-weight relationships were best described by **power regression** formulas ($y = ax^b$). Live and dry shell weights of individual mussels served as the dependent variables and shell length and height as the independent variables in growth curves. Regression formulas were used to calculate live weight and dry shell weight given either shell length or height.

Mussel age-frequency histograms were constructed for five commercial species, *A. plicata*, *M. nervosa*, *Q. quadrula*, *Q. metanevra*, *Q. pustulosa*, and two non commercial species, *E. lineolata* and *O. reflexa*. These histograms represented **all** individuals regardless of whether their ages had been determined from counting growth bands (estimated) or calculated from 3rd order

Species	1987			1994-95			
	Aged		Weighed	Aged		Weighed	
	n	%	n	n	%	n	%
Amblema plicata	377	100	---	137	20.2	167	24.7
Megalonaias nervosa	131	100	---	79	36.9	98	45.8
Quadrula quadrula	54	100	---	33	21.6	57	37.3
Quadrula metanevra	78	100	---	12	7.3	32	19.4
Quadrula pustulosa	714	100	---	146	10.9	210	15.7
Ellipsaria lineolata	310	100	---	---	---	106	6.6
Obliquaria reflexa	153	100	---	---	---	86	14.9

Table 1. Number and percent of the individuals from each mussel species collected in Reach 15 of the UMR which were aged and weighed in 1987 and 1994-95.

polynomial regression equations (calculated). In 1987, all mussels were aged, therefore these histograms represent only estimated ages. In 1994-95, only from 7.3% to 36.9% of the individuals from each species were aged (Table 1), therefore these histograms consist primarily of mussels with calculated ages. *Ellipsaria lineolata* and *O. reflexa* were not aged in the current study, instead we used 1987 regression formulas to calculate their ages based on observed shell lengths.

Mortality

Mortality estimates were based on the percentage of recently dead mussels in our quantitative samples. Some researchers contend this method results in overestimation due to the misidentification of old dead shells as recently dead. In the present survey, we used the same method and definition we used in 1983, 1985, and 1987; thereby at least allowing comparisons among mussel surveys conducted by the INHS in the past decade. We have also conducted field trials to validate this method in the Illinois River: these data indicate our assessment of mortality is conservative and actual mortality rates are likely higher (INHS, unpublished data). This is due to the rapid discoloration, breakdown of nacre, and separation of the hinge ligament which often resulted in a mussel being identified as old dead when it had died within the past three months.

Zebra Mussels

Mean zebra mussel densities (by site and date) were determined from either the same quantitative samples from which unionids were collected (July and August 1994) or from a separate set of samples in which only zebra mussels were counted (July 1995) (Table H-1). Length-frequency histograms of zebra mussels collected at the Illiniwek site (RM 492.4) on five dates between July 1994 and September 1995 were used to evaluate population size structure and recruitment events.

Zebra mussel infestation of Unionid mussels was reported as **% Infestation** (the number of unionids with one or more attached zebra mussels) and **Degree of Infestation** (the number of zebra mussels attached to an individual unionid). The degree of infestation of all unionids on each sample date was used to calculate a mean, standard deviation, and range for each study site and unionid species.

Results and Discussion

Species Richness and Abundance

From July 1994 through September 1995 we collected a total of 7,107 native mussels representing twenty-six species from the three study sites in Reach 15 (Table A-3 and A-4). Illiniwek had the most species (25) followed by Case-IH (23) and Sylvan Slough (20) (Table

A-3). Four live threatened or endangered species were collected at one or more of the three sites: the federally endangered *Lampsilis higginsi* (Higgins eye), the state endangered *Plethobasus cyphyus* (Sheepnose) and *Cumberlandia monodonta* (Spectacle case), and the state threatened *Ellipsaria lineolata* (Butterfly) (Table A-6).

The three most abundant species in Reach 15 were *Truncilla truncata* (Deertoe), *Ellipsaria lineolata* (Butterfly), and *Quadrula pustulosa* (Pimpleback). In combination, these three species constituted 53% to 73% of the unionid populations at the three study sites (Table A-6). *Amblema plicata* (Threeridge) ranked seventh in overall abundance at Sylvan Slough (3.3/m^2; 6.0%), third at Case-IH (14.0/m^2; 15.6%), and fourth at Illiniwek (10.3/m^2; 8.6%). *Megalonaias nervosa* (Washboard) ranked between sixth and eighth in overall abundance and only accounted for 2-4% of the unionids collected at Reach 15 sites between 1994 and 1995.

Mean unionid densities at the three sites sampled in the 1994-95 survey increased significantly ($p \leq 0.001$) in the upriver direction (i.e., Sylvan Slough (53.4/m^2) < Case-IH (86.7/m^2) < Illiniwek (118.3/m^2)) (Table A-12). This is likely attributable to the similar trend in mean densities of three of the more abundant species, *E. lineolata*, *T. truncata*, and *A. plicata* (Table A-7). Only two species, *Quadrula metanevra* (Monkeyface) and *Truncilla donaciformis* (Fawnsfoot), had densities which increased significantly in the downriver direction (Illiniwek < Case-IH < Sylvan Slough).

Temporal trends in unionid abundance reflect a significant decline ($p \leq 0.001$) in mean unionid density at both Sylvan Slough (refuge) and Case-IH (harvested) over the past decade (Table A-12). Between 1985 and 1995, six mussel species (*A. plicata*, *M. nervosa*, *Leptodea fragilis*, *Potamilus alatus*, *Potamilus ohiensis*, and *U. imbecillis*) showed statistically significant declines ($p < 0.001$) in mean densities at the Sylvan Slough site (Table A-9). During the same time period, four species (*L. fragilis*, *P. alatus*, *T. truncata*, and *T. donaciformis*) declined ($p \leq 0.01$) at the Case-IH site (Table A-11). No species showed a significant increase at either of the two sites.

Mean overall unionid density at Illiniwek (98 samples, 118.3/m^2) and Sylvan Slough (116 samples, 53.4/m^2) were likely ($p = 0.05$) within 10% of their actual densities (Table B-1) based on the statistical technique described by Green (1979). Greater sample variance and fewer samples at Case-IH (72 samples, 86.7/m^2) resulted in an estimate within 15% of the actual density. Although fewer samples were collected during quantitative sampling in Reach 15 during 1983 and 1987, density estimates were still within 20% of the actual density at Sylvan Slough and between 30%-40% at Case-IH (Table B-1). We also applied this technique (Green 1979) to density estimates for individual species (Tables F-2 to F-4). Density estimates for abundant species at each site were the only ones which had a 95% probability of being within 20%-30% of their actual densities (Tables B-2 to B-4). To estimate the uncommon or rare species with the same level of precision would require an unreasonably large number of samples (i.e., 1,000 to 61,000 samples).

Density histograms based on shell height for all commercial mussel species collected over the past decade at Reach 15 sites exhibit a truncated distribution pattern which coincides with the minimum commercial size limit (Appendix D). Possible explanations for this trend are: (1) shortly after reaching the minimum size limit all commercial mussel species experience a period of near complete mortality, (2) the minimum size limit is at or near the maximum achievable size for commercial species in Reach 15, or (3) commercial musselors are extremely efficient at removing adult mussels from the population once they reach the minimum size limit. Our data from Reach 15 mussel populations over the last decade indicate that the latter is the most likely explanation for the truncated distributions. For example, at Sylvan Slough in 1983 and 1985 (Figure D-5) and at Case-IH in 1987 (Figure D-10) there were relatively large cohorts of adult *A. plicata* in the 60- to 70-mm size intervals, just below the minimum commercial size limit. Within 2 to 4 years these apparently strong cohorts were missing or not evident from the population as they were not identifiable in subsequent histograms. The disappearance of these cohorts probably occurred within a few years after they grew beyond the minimum commercial size limit. Sylvan Slough was designated a mussel refuge in 1988, and yet seven years later (1995) the distribution patterns of the primary commercial species remain truncated at the minimum size limit similar to harvested beds, suggesting that illegal harvest occurred within this refuge. In fact, individuals have been prosecuted for illegally harvesting mussels in the Sylvan Slough refuge (Scott Wright, IDNR Conservation Warden, personal communication)

The 1994-95 densities of commercial mussels with heights greater than the minimum size limit (legal-size) is extremely low at all three Reach 15 sites (Appendix C). The mean density of legal-size *A. plicata* ranged from a low of 0.24/m^2 at Sylvan Slough to a high of 1.12/m^2 at Case-IH (Table D-1). Based on these density estimates there are from 2,424 (Sylvan Slough) to 11,314 (Illiniwek) legal-size *A. plicata*/hectare (970 to

4,526/acre) (Table G-8). There are even fewer legal-size *M. nervosa*, with densities from 0.06/m^2 to 0.24/m^2 or 606 (Case-IH) to 2,424 (Illiniwek) legal-size mussels per hectare (242 to 970/acre) (Table G-8).

Recruitment

Recent recruitment estimates from the ten species we evaluated in 1994-95 indicate a high degree of variability among species and study sites (Table F-1). Mean density of recent recruits ranged from a low of 0.01/m^2 (*M. nervosa*) to a high of 3.97/m^2 (*Q. pustulosa*). Densities of recent recruits were similar among sites for six mussel species (*A. plicata*, *M. nervosa*, *Q. metanevra*, *Q. pustulosa*, *Q. quadrula*, and *O. reflexa*). The remaining four species (*E. lineolata*, *L. fragilis*, *T. truncata*, and *T. donaciformis*) showed significant differences in recruitment among sites; for example, the density of recently recruited *E. lineolata* was significantly greater at Illiniwek (3.34/m^2) than at the two other sites (Case-IH = 0.56/m^2 and Sylvan Slough = 0.65/m^2) (Table F-1). Species with the highest mean recruitment densities, *Q. pustulosa* (4.0/m^2), *E. lineolata* (1.5/m^2), and *T. truncata* (1.5/m^2), were also the three most abundant species collected from Reach 15 in the present survey (Table A-5). Some species showed little evidence of recent recruitment at one or more of the study sites; we did not collect any *M. nervosa* or *Q. metanevra* (Monkeyface) less than 30 mm in length from either of the two harvested beds (Case-IH and Illiniwek) and only one *M. nervosa* and two *Q. metanevra* at the refuge bed (Sylvan Slough).

Recruitment information from Sylvan Slough (Table F-1) and Case-IH (Table F-3) between 1983 and 1995 demonstrates the unpredictable nature of mussel recruitment. Some species exhibit fairly constant recruitment (e.g., *Q. pustulosa*) with relatively high densities of young mussels in most years, while others show evidence of sporadic recruitment (e.g., *T. truncata*, *T. donaciformis*, and *M. nervosa*). Interpretation of recruitment information is difficult since we know very little about the natural reproductive patterns of mussel species and how they are affected by environmental conditions (i.e., water temperature, floods, turbidity, etc.), biological factors (i.e., mussel abundance, host abundance, peak gravidity, etc.), or anthropogenic stressors (i.e., commercial harvest, recreational or commercial boat traffic, pollutants, etc.).

Density distributions based on shell length (Appendix C) and age (Appendix F) facilitate the identification of strong or weak cohorts which can be used to ascertain long-term trends in recruitment. For example, most mussel species typically showed a modal age distribution produced by years of significant recruitment (strong cohorts) and years with poor recruitment and/or survival (weak cohort). Two mussel species, *M. nervosa* and *A. plicata*, which show very different recruitment patterns are discussed in greater detail.

(1) *M. nervosa* exhibited relatively low densities of recent recruits ($\leq$ 1.0/m^2) in most quantitative surveys conducted by INHS in Reach 15 in the last ten years (1985-1995) (Tables F-1 to F-3). Density distributions based on age and shell length from 1994-95, show few young (age $\leq$ 7 years) (Figures E-1, E-3, and E-5) or small mussels (shell length $\leq$ 85mm) (Figure C-2). In fact, the last significant recruitment by *M. nervosa* at our sites probably occurred in 1984-85 and can be identified in nearly all density distributions (age, length, and height) since 1987; for example, the density distribution (based on age) for *M. nervosa* collected in 1987 Sylvan Slough shows a strong (6.88/m^2) age 2-3 cohort (Figure E-2), which can be identified in the density distribution from 1994-95 as an age 9-10 cohort (Figure E-1). This indicates *M. nervosa* experiences infrequent recruitment success, possibly only once during this ten year period. Heath et al. (1988) suggested an approximate 7-year recruitment cycle for *M. nervosa* in the Wisconsin portion of the UMR.

(2) *A. plicata* exhibited a more consistent recruitment pattern, with recent recruit densities typically between 0.23/m^2 and 0.68/m^2 in 1985 and 1995 (Tables F-1, F-2, and F-3). Density distributions from all study sites (1983-1995), based on age (Figures E-1 to E-6), shell length (Figures C-10 and C-20), and shell height (Figures D-1, D-5, and D-10), show that *A. plicata* successfully recruit individuals to their population each year and occasionally produce an especially abundant cohort (1985-86, see Appendix E).

Age and Growth

We observed strong non-linear age-size (Tables G-3 and G-4) and size-weight (Table G-7) relationships for the five commercial mussel species (*A. plicata*, *M.*

nervosa, *Q. quadrula*, *Q. pustulosa*, and *Q. metanevra*) evaluated from Reach 15. Growth curves (Appendix G, Part IV) and calculated size-at-age (Appendix G, Part III) indicate growth rates of Reach 15 mussels are similar to other UMR populations (Woody 1988; Heath et al. 1988) and much lower than populations in the Illinois River (Whitney et al., unpublished data). Growth rates decreased sharply with increasing age. Annual increase in length for the five species can be summarized as: (1) mussels aged 1 to 5 grow greater than 7 mm/yr (up to 17 mm/yr for *M. nervosa*), (2) mussels aged 6 to 11 grow from 4 to 10 mm/yr, (3) mussels aged 12 to 17 grow from 2 to 4 mm/yr, and (4) mussels aged greater than 18 grow less than 2 mm/yr. Species specific annual growth rates can be determined from Appendix G, Part III.

On average, sexual maturity of most commercial mussel species (*A. plicata*, *M. nervosa*, *Q. pustulosa*, *Q. metanevra*, and *Q. quadrula*) occurs during their seventh or eighth years, with a range from 5 to 12 years of age (Table G-2).

The time required for a commercial species to reach minimum harvestable size ranged from 19 to 24 years; *M. nervosa* took the longest, requiring 24 years to reach a shell height of 101.60 mm (4 inch), *A. plicata* required 21 years to reach a shell height of 69.85 mm (2.75 inch), and the three *Quadrula* species required 19 to 21 years to reach a shell height of 63.5 mm (2.5 inch). These values are similar to the results from other growth studies in the UMR (21 years for *M. nervosa*, [Heath et al. 1988]) and nearly double the time required by the same species in the Illinois River (e.g., *A. plicata* reached minimum commercial size in 9 years in Peoria Reach and 13 years in the Alton Reach of the Illinois River [INHS, unpublished data]).

Mortality

Mean unionid mortality at Sylvan Slough reached 30.4% in 1983; eight mussel species had mean mortalities greater than 25%, including *M. nervosa* (45%), *Q. pustulosa* (37.6%), *A. plicata* (34.9%), and *T. truncata* (33.3%) (Table A-8). Since 1983, mortality rates have generally declined; however, these high mortalities in the eighties likely contributed to the significant decline in abundance of many of these species during the past decade (Table A-9).

During the current survey (1994-95), mean unionid mortality at the three study sites was estimated at 0.81% at Illiniwek, 1.15% at Sylvan Slough, and 4.27% at Case-IH. We are concerned about the apparent increase in mortality at Case-IH, which has increased from 1.88% in 1987 to 4.27% in 1994. *Amblema plicata* showed increased mortality from 1.52% in 1987 to 6.67% 1994 (Table A-10). Overall mortality rates of the other two sites appear to be within acceptable levels, since they are typical of most mussel populations we have sampled (INHS, unpublished data).

Zebra Mussels

We believe zebra mussels first arrived in Reach 15 in late 1991 or early 1992. The largest individual collected in July 1994 measured 28.35 mm. From growth studies in the Illinois River, this individual would have been from 2 to 3 years of age (INHS, unpublished data). Length-frequency histograms (Figure H-1) indicate that at least one and at most two zebra mussel cohorts settled in Reach 15 in both 1994 and 1995. Growth rates of zebra mussels in Reach 15 (determined from length-frequency histograms) are similar to those observed in the Illinois River in 1993 (INHS, unpublished data), with mussels reaching a length of 17 to 20 mm in their first growing season.

Zebra mussel densities at Reach 15 study sites have increased significantly between July 1994 and July 1995 (Table H-1). The highest densities have consistently been found at the Illiniwek site where mean density increased exponentially, from 1.7/m^2 in July 1994 to 2,519/m^2 in July 1995. During the same period, mean zebra mussel density at Sylvan Slough increased from 0.6/m^2 to 426.0/m^2. Much or the rivers flow is diverted away from Sylvan Slough by a rock seawall (Figure 3). This diversion may be the reason why fewer planktonic zebra mussel larvae (veligers) settled in Sylvan Slough than at Illiniwek.

The infestation of native unionids at study sites increased from less than 1% in July 1994 to 48.9% at Illiniwek and 40.1% at Sylvan Slough in September 1995 (Figure H-2). Similarly, the mean degree of infestation increased from 0.0 to 2.31/unionid at Illiniwek and from 0.0 to 1.29/unionid at Sylvan Slough from July 1994 to September 1995 (Table H-3 and H-4). The maximum number of zebra mussels collected on an individual mussel was 37 on a *Q. pustulosa* collected from the Illiniwek site in September 1995 (Figure H-2). From our experience with zebra mussels in the Illinois River, we believe this degree of infestation is insufficient to create negative effects (i.e., reduced growth, restricted mobility, increased mortality) on unionid mussels. Ricciardi et al. (1995) used linear regression models to predict the intensity and impact of zebra mussel infestation on native unionids from field densities; their models predict severe

unionid mortality (> 90%) occurs when zebra mussel densities and mean infestation intensity reach 6,000/m^2 and 100/unionid. We predict that by 1996 or 1997 unionid mussels in Reach 15 of the UMR will experience significantly greater infestations by zebra mussels and will subsequently suffer reduced fitness and increased mortality.

Management Recommendations

A primary objective of this comprehensive study was to provide resource managers with critical information necessary for the evaluation of management and conservation strategies to protect, preserve, or enhance freshwater mussels in the Upper Mississippi River.

Analysis of quantitative data collected on mussel populations in Reach 15 of the UMR over the past decade shows that mussel populations have declined significantly, recruitment of many species is sporadic, mortality has been relatively high, growth rates are generally slow, illegal harvest has occurred in the mussel refuge, and zebra mussel abundance and infestation of unionids are increasing rapidly. We believe the following management actions could help to conserve mussel populations in Reach 15 and possibly throughout the entire UMR.

(1) Close the commercial harvest of live *Megalonaias nervosa* (Washboard). Studies conducted by the INHS in Reach 15 since 1983 indicate *M. nervosa* populations have suffered a significant ($p \leq 0.001$) decline in mean density (Table A-9), most likely the result of extensive commercial exploitation, unexplained die-offs from 1982 to 1985, and only one substantial recruitment event in the past ten years (Figure F-3).

Commercial harvest reports from Illinois (Williamson 1994) and Iowa (Ackerman 1996) indicate a significant decline in the reported catch of live washboard despite a significant increase in fishing effort. In the Illinois portion of the Mississippi River 1,092,330 pounds of live washboard were reportedly harvested in 1987, compared to 49,967 pounds in 1994. In the Iowa portion of the Mississippi, 296,988 pounds of live washboard were harvested in 1986, compared with only 1254 pounds in 1992. In the past eight years the average price paid for live washboards has increased nearly 1000%, increasing from $0.22/lb in 1987 to $2.40/lb in 1995. As the number of live washboards has decreased, buyers have turned to dead (relic) washboards to meet the increasing demand of their Japanese consumers. In 1995 the average price paid for relic shell was $1.40/lb.

In the late 1980's, Fritz (1988) recommended a larger minimum harvest size or a ban on the harvest of washboard in some reaches of the Mississippi River as the only alternatives to prevent the serious stock depletion of this species. Commercial harvest reports from 1987 to 1995 and results from the present mussel survey of Reach 15 indicate washboard stocks may be at or below the critical level required to maintain themselves, even without additional commercial pressure. At this point, merely increasing the size restrictions is an unacceptable alternative, as it would still allow the further depletion of the reproductive stock. If commercial harvest of live washboard is allowed to continue unchecked, they may soon be extirpated from some reaches of the UMR.

(2) Establish entire reaches as mussel refuges. Although we support the need and rationale for mussel refuges, we believe the current mussel refuges only exist on paper and subsequently do not provide the services for which they were intended. Our studies in Reach 15 suggest illegal harvest has occurred in the Sylvan Slough refuge, since all commercial species collected within the refuge demonstrate a truncated size distribution at the minimum commercial size limit (Appendix D), a characteristic of harvested areas. In fact, individuals have been prosecuted for harvesting mussels in Sylvan Slough and other UMR mussel refuges (Scott Wright, IDNR Conservation Warden, personal communication). According to Wright, enforcement is difficult in that shellers must be caught harvesting within the refuge boundaries. Once removed from the refuge, illegally harvested shells can not be distinguished from legal shells taken elsewhere. If an entire reach were designated as a refuge, any persons possessing shells on the water or at access sites (boat ramps) within the designated reach would be subject to prosecution.

The Upper Mississippi River Conservation Committee's (UMRCC) mussel ad hoc committee, which is composed of representatives from the five UMR states, recently recommended that two entire reaches of the Mississippi River be set aside as mussel refuges. An ideal reach for designation as a refuge would have the following characteristics: (1) good baseline data (mussel recruitment, density, diversity, harvest, etc.), (2) high density of commercial and non-commercial species, (3) high species diversity, (4) presence of threatened, endangered, or special concern species, and (5) conducive to enforcement (limited access, law enforcement presence, and public support). We believe Reach 15 has all these characteristics and would be a good candidate for a mussel refuge.

(3) Develop population models to guide and assist the management of mussels. Mussel populations are in urgent need of protection and management, but there is a lack of information on which sound management practices could be based. Among the very basic questions which need to be answered are: are mussel populations undergoing long-term decline? If so, what are the contributing factors and their relative importance. For example, is the problem caused by reduced recruitment, increased mortality (due to harvest, zebra mussels, and natural causes), or some combination of both? What is a sustainable harvest level? What age classes or size classes should be protected from harvest? These are the types of questions addressed by population models that are in common use in fish and wildlife management, e.g., for managing the deer herd in Illinois. Similar population models need to be developed to guide and assist the management of mussels.

The recommended approach in developing these models is to gather data that will be immediately useful to resource managers in the UMR in regulating harvest of all commercial species, but at the same time begin development of a population model for one commercial species. Field and laboratory data would be used in the model, which would eventually simulate the outcome of various management decisions and varying degrees of zebra mussel impacts. The initial model should be for *A. plicata* (Threeridge) which makes up most of the commercial harvest in the UMR and is common to most of the medium and large rivers of the midwest. The exact modeling approach should be left to the discretion of the modeler, but an example is the dynamic pool approach described by Pitcher and Hart (1982).

Although a crude model can probably be developed in one year, refinement, calibration, and verification of the model is likely to take longer, especially since it will require at least 5 years of field work, perhaps more. The reasons for such a long-term program are: (1) a long time series of data is required to capture sporadic recruitment events and associate these with causative factors, and (2) it will take a long time to collect data that were not collected in earlier studies (fecundity, age/shell length relationships, repeated measures of marked individuals to determine growth). A long-term commitment should be made to this program, because it would be a waste of resources to start a 5-year growth study involving recapture of marked mussels and then not complete it because of lack of funding.

Improved management of mussels does not have to be postponed until the model is completed however, because the field investigations themselves would provide useful information on the status of mussel populations. The technical basis for management decisions should improve rapidly as the model and its information base improve year to year.

(4) Monitor zebra mussel densities and impacts on native mussels in the Mississippi River. Zebra mussel densities and infestation of native unionid mussels have increased significantly since 1994. Between July 1994 and July 1995, zebra mussel densities at the Illiniwek study site increased from a mean of $1.5/m^2$ to $2,519/m^2$ (Table H-1) and infestation of native unionids increased from less than 1% to 48.9% (Figure H-2). As zebra mussel densities and unionid infestation continue to increase so will the likelihood of widespread unionid mortality. Without continuation of monitoring of Mississippi River zebra mussel populations to determine abundance and their effects on native unionid mussels, it will be difficult to justify the implementation of future mitigation strategies. Reach 15 would serve as an ideal location to continue to monitor the buildup and impacts of zebra mussel populations since we have quantitative baseline information on their abundance and infestation of unionids.

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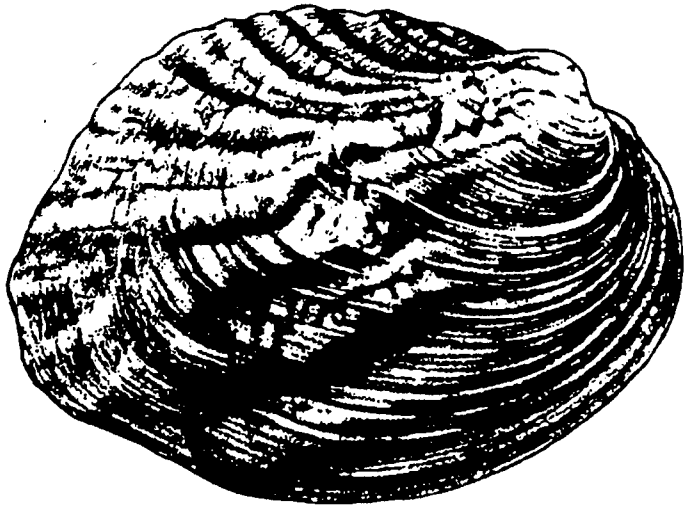
Appendices

A comprehensive evaluation of three mussel beds in Reach 15 of the Upper Mississippi River



Center for Aquatic Ecology

Scott D. Whitney, K. Douglas Blodgett, and Richard E. Sparks

Illinois Natural History Survey
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Aquatic Ecology Technical Report 96/7

List of Appendices

Appendix A

Unionid Species Richness and Abundance

Reach 15 of the Upper Mississippi River

Appendix A
Unionid Species Richness and Abundance
Reach 15 of the Upper Mississippi River

Table A-1. Summary of quantitative unionid mussel sampling in Reach 15 of the Upper Mississippi River during surveys conducted by the Illinois Natural History Survey between (a) 1994-95 and (b) 1983-87.

(a) 1994-95	Number of quantitative samples					
	0.25-m²			1-m²		Area
Site	July '94	Aug '94	July '95	Sept '95	Total	(m²)
Sylvan Slough (RM 485.8)	80	----	30	6	116	34
Case-IH (RM 488.5)	50	22	----	----	72	18
Illiniwek (RM 492.4)	40	22	30	6	98	29
Total	**170**	**44**	**60**	**12**	**286**	**81**

(b) 1983-87	Number of quantitative samples				
	1-m²				Area
Site	May '83	Sept '85	June '87	Total	(m²)
Sylvan Slough (RM 485.8)	4	8	8	20	20
Case-IH (RM 488.5)	----	6	8	14	14
Total	**4**	**14**	**16**	**34**	**34**

Table A-2. Mean, standard deviation (SD), and range of live mussel densities (no./m²) from three sites in Reach 15 of the Upper Mississippi River sampled between (a) 1994-95 and (b) 1983-87.

(a) 1994-95	Mean ± SD/range of live mussel densities (no./m²)				
Site	July '94	Aug '94	July '95	Sept '95	Overall
Sylvan Slough (RM 485.8)	48.2±20.8 (0-100)	---- ----	68.9±30.3 (12-124)	45.0±15.0 (21-63)	53.4±25.0 (0-124)
Case-IH (RM 488.5)	97.0±51.1 (8-232)	63.2±41.1 (4-180)	---- ----	---- ----	86.7±50.6 (4-232)
Illiniwek (RM 492.4)	150.7±42.7 (56-264)	124.5±41.4 (56-188)	82.7±34.2 (24-180)	83.7±15.3 (66-110)	118.3±48.8 (24-264)

(b) 1983-87	Mean ± SD/range of live mussel densities (no./m²)		
Site	May '83	Sept '85	June '87
Sylvan Slough (RM 485.8)	89.5±13.5 (75-109)	100.1±21.6 (69-132)	115.4±17.2 (93-149)
Case-IH (RM 488.5)	---- ----	139.2±62.1 (62-216)	289.8±25.0 (214-515)

Table A-3. Number of unionid mussel species collected by the Illinois Natural History Survey during quantitative sampling at three sites in Reach 15 of the Upper Mississippi River between 1983 and 1995.

Site	Number of unionid species				
	1983	1985	1987	1994-95	Total
Sylvan Slough (RM 485.8)	18	21	21	23	25
Case-IH (RM 488.5)	----	19	23	20	24
Illiniwek (RM 492.4)	----	----	----	25	25
Total	**18**	**21**	**24**	**26**	**26**

Table A-4. Scientific and common names of native unionid species collected in Reach 15 of the Upper Mississippi River during quantitative mussel surveys conducted by the Illinois Natural History Survey, 1983-95. Taxonomy follows Cummings and Mayer, 1992.

Scientific	Common
1. *Actinonaias ligamentina* (Lamarck, 1819)	Mucket
2. *Amblema plicata* (Say, 1817)	Threeridge
3. *Arcidens confragosus* (Say, 1829)	Rock-pocketbook
4. *Cumberlandia monodonta* (Say, 1829)	Spectaclecase
5. *Ellipsaria lineolata* (Rafinesque, 1820)	Butterfly
6. *Fusconaia flava* (Rafinesque, 1820)	Wabash pigtoe
7. *Lampsilis cardium* (Rafinesque, 1820)	Plain pocketbook
8. *Lampsilis higginsi* (Lea, 1857)	Higgins eye
9. *Lasmigona complanata* (Barnes, 1823)	White heelsplitter
10. *Leptodea fragilis* (Rafinesque, 1820)	Fragile papershell
11. *Ligumia recta* (Lamarck, 1819)	Black sandshell
12. *Megalonaias nervosa* (Rafinesque, 1820)	Washboard
13. *Obliquaria reflexa* (Rafinesque, 1820)	Threehorn wartyback
14. *Obovaria olivaria* (Rafinesque, 1820)	Hickorynut
15. *Plethobasus cyphyus* (Rafinesque, 1820)	Sheepnose
16. *Potamilus alatus* (Say, 1817)	Pink heelsplitter
17. *Potamilus ohiensis* (Rafinesque, 1820)	Pink papershell
18. *Pyganodon grandis* (Say, 1829)	Giant floater
19. *Quadrula metanevra* (Rafinesque, 1820)	Monkeyface
20. *Quadrula nodulata* (Rafinesque, 1820)	Wartyback
21. *Quadrula pustulosa* (Lea, 1831)	Pimpleback
22. *Quadrula quadrula* (Rafinesque, 1820)	Mapleleaf
23. *Strophitus undulatus* (Say, 1817)	Squawfoot
24. *Truncilla donaciformis* (Lea, 1828)	Fawnsfoot
25. *Truncilla truncata* (Rafinesque, 1820)	Deertoe
26. *Utterbackia imbecillis* (Say, 1829)	Paper pondshell

Table A-5. Species collected from three sites in Reach 15 of the Upper Mississippi River during the 1994-95 survey by the Illinois Natural History Survey. Species for each site are shown in order of decreasing abundance (avg. density). Class refers to : A* = very abundant (> 20.01/m²); A = abundant (10.01 to 20.00/m²); C = Common (1.01 to 10.00/m²); UC = uncommon (0.34 to 1.00/m²); and R = rare (< 0.33/m²).

Sylvan Slough (485.8)		Case-IH (488.6)		Illiniwek (492.4)		Overall (Reach 15)	
Rank	**Species**	**Rank**	**Species**	**Rank**	**Species**	**Rank**	**Species**
1. *Q. pustulosa*	A	1. *Q. pustulosa*	A*	1. *T. truncata*	A*	1. *T. truncata*	A*
2. *T. truncata*	C	2. *T. truncata*	A	2. *E. lineolata*	A*	2. *E. lineolata*	A
3. *E. lineolata*	C	3. *A. plicata*	A	3. *Q. pustulosa*	A	3. *Q. pustulosa*	A
4. *T. donaciformis*	C	4. *E. lineolata*	A	4. *A. plicata*	A	4. *A. plicata*	C
5. *Q. metanevra*	C	5. *O. reflexa*	C	5. *O. reflexa*	A	5. *O. reflexa*	C
6. *O. reflexa*	C	6. *M. nervosa*	C	6. *L. fragilis*	C	6. *M. nervosa*	C
7. *A. plicata*	C	7. *Q. quadrula*	C	7. *M. nervosa*	C	7. *L. fragilis*	C
8. *M. nervosa*	C	8. *L. fragilis*	C	8. *Q. quadrula*	C	8. *T. donaciformis*	C
9. *Q. quadrula*	C	9. *T. donaciformis*	C	9. *T. donaciformis*	C	9. *Q. quadrula*	C
10. *L. fragilis*	C	10. *Q. metanevra*	UC	10. *L. cardium*	UC	10. *Q. metanevra*	C
11. *P. cyphyus*	R	11. *Q. nodulata*	UC	11. *F. flava*	UC	11. *L. cardium*	UC
12. *Q. nodulata*	R	12. *F. flava*	UC	12. *P. grandis*	UC	12. *F. flava*	UC
13. *L. recta*	R	13. *L. cardium*	UC	13. *U. imbecillis*	UC	13. *P. grandis*	R
14. *L. cardium*	R	14. *P. grandis*	UC	14. *P. alatus*	UC	14. *Q. nodulata*	R
15. *U. imbecillis*	R	15. *P. alatus*	R	15. *Q. metanevra*	R	15. *P. alatus*	R
16. *P. alatus*	R	16. *O. olivaria*	R	16. *L. recta*	R	16. *U. imbecillis*	R
17. *F. flava*	R	17. *L. recta*	R	17. *A. confragosus*	R	17. *L. recta*	R
18. *P. grandis*	R	18. *L. complanata*	R	18. *L. complanata*	R	18. *P. cyphyus*	R
19. *L. higginsi*	R	19. *S. undulatus*	R	19. *O. olivaria*	R	19. *L. higginsi*	R
20. *A. ligamentina*	R	20. *L. higginsi*	R	20. *L. higginsi*	R	20. *L. complanata*	R
21. *A. confragosus*	R			21. *A. ligamentina*	R	21. *A. confragosus*	R
22. *S. undulatus*	R			22. *S. undulatus*	R	22. *O. olivaria*	R
23. *O. olivaria*	R			23. *Q. nodulata*	R	23. *A. ligamentina*	R
				24. *C. monodonta*	R	24. *S. undulatus*	R
				25. *P. ohiensis*	R	25. *C. monodonta*	R
						26. *P. ohiensis*	R
A*=0:A=1:C=9:UC=0:R=1		**A*=1:A=3:C=5:UC=5:R=6**		**A*=2:A=3:C=4:UC=5:R=11**		**A*=1:A=2:C=7:UC=2:R=14**	

Table A-6. Number, density, relative abundance, and mortality of unionid mussels at three sites in Reach 15 of the Upper Mississippi River. These values represent a compilation of all quantitative samples collected at Sylvan Slough (RM 485.8), Case-IH (RM 488.5), and Illiniwek (RM 492.4) during the 1994-95 mussel survey conducted by the Illinois Natural History Survey.

Reach 15 : 1994-95

Species	Number live			Density (no./m²) Sylvan Slough (RM 485.8)		Case-IH (RM 488.5)		Illiniwek (RM 492.4)		Relative abundance (%)			Overall mortality (%)		
	485.8	488.5	492.4	Mean	SD	Mean	SD	Mean	SD	485.8	488.5	492.4	485.8	488.5	492.4
1. *Actinonaias ligamentina*	3	0	4	**0.10**	0.64	**0.00**	0.00	**0.12**	0.90	0.17	0.00	0.11	0.00	0.00	0.00
2. *Amblema plicata*	102	252	323	**3.25**	4.26	**14.00**	12.31	**10.34**	7.51	5.95	15.59	8.55	3.77	6.67	1.22
3. *Arcidens confragosus*	2	0	5	**0.07**	0.53	**0.00**	0.00	**0.20**	0.89	0.12	0.00	0.13	0.00	0.00	0.00
4. *Cumberlandia monodonta*	0	0	1	**0.00**	0.00	**0.00**	0.00	**0.04**	0.40	0.00	0.00	0.03	0.00	0.00	0.00
5. *Ellipsaria lineolata*	218	248	1133	**6.80**	5.73	**13.78**	15.11	**35.02**	18.14	12.71	15.35	30.01	0.00	1.59	0.09
6. *Fusconaia flava*	3	11	17	**0.10**	0.64	**0.61**	1.72	**0.51**	1.44	0.17	0.68	0.45	0.00	0.00	0.00
7. *Lampsilis cardium*	8	9	23	**0.25**	0.96	**0.50**	1.48	**0.63**	1.45	0.47	0.56	0.61	0.00	0.00	0.00
8. *Lampsilis higginsi*	3	1	4	**0.10**	0.64	**0.06**	0.47	**0.13**	0.70	0.17	0.06	0.11	0.00	0.00	0.00
9. *Lasmigona complanata*	0	2	5	**0.00**	0.00	**0.11**	0.66	**0.16**	0.80	0.00	0.12	0.13	0.00	0.00	0.00
10. *Leptodea fragilis*	55	37	113	**1.78**	3.22	**2.06**	3.66	**3.83**	4.36	3.21	2.29	2.99	0.00	5.13	1.74
11. *Ligumia recta*	11	2	9	**0.28**	0.99	**0.11**	0.66	**0.24**	0.96	0.64	0.12	0.24	0.00	0.00	0.00
12. *Megalonaias nervosa*	66	65	83	**2.24**	3.18	**3.61**	6.52	**2.77**	3.16	3.85	4.02	2.20	0.00	0.00	0.00
13. *Obliquaria reflexa*	126	165	288	**3.94**	4.03	**9.17**	9.45	**9.93**	8.60	7.35	10.21	7.63	2.33	1.20	1.71
14. *Obovaria olivaria*	1	2	4	**0.03**	0.37	**0.11**	0.66	**0.13**	0.70	0.06	0.12	0.11	0.00	0.00	0.00
15. *Plethobasus cyphyus*	10	0	0	**0.32**	1.31	**0.00**	0.00	**0.00**	0.00	0.58	0.00	0.00	0.00	0.00	0.00
16. *Potamilus alatus*	4	3	10	**0.14**	0.74	**0.17**	0.80	**0.34**	1.24	0.23	0.19	0.26	0.00	57.14	0.00
17. *Potamilus ohiensis*	0	0	1	**0.00**	0.00	**0.00**	0.00	**0.04**	0.40	0.00	0.00	0.03	0.00	0.00	0.00
18. *Pyganodon grandis*	3	7	16	**0.10**	0.83	**0.39**	1.36	**0.50**	1.65	0.17	0.43	0.42	0.00	0.00	0.00
19. *Quadrula metanevra*	142	15	8	**4.42**	5.11	**0.83**	2.00	**0.33**	1.24	8.28	0.93	0.21	0.00	0.00	0.00
20. *Quadrula nodulata*	9	11	2	**0.29**	1.27	**0.61**	1.72	**0.05**	0.42	0.52	0.68	0.05	0.00	0.00	0.00
21. *Quadrula pustulosa*	463	378	499	**14.15**	9.89	**21.00**	19.44	**16.17**	12.11	27.00	23.39	13.22	1.28	2.33	0.80
22. *Quadrula quadrula*	60	47	46	**1.85**	3.58	**2.61**	3.73	**1.33**	2.19	3.50	2.91	1.22	0.00	4.08	0.00
23. *Strophitus undulatus*	1	1	7	**0.03**	0.37	**0.06**	0.47	**0.09**	0.58	0.06	0.06	0.19	0.00	0.00	0.00
24. *Truncilla donaciformis*	137	36	29	**4.49**	6.50	**2.00**	3.84	**1.02**	1.99	7.99	2.23	0.77	2.84	14.29	3.33
25. *Truncilla truncata*	281	324	1132	**8.44**	7.29	**18.00**	11.43	**35.59**	21.26	16.38	20.05	29.98	1.06	7.16	1.14
26. *Utterbackia imbecillis*	7	0	14	**0.22**	0.90	**0.00**	0.00	**0.42**	1.55	0.41	0.00	0.37	0.00	0.00	6.67
Totals	**1715**	**1616**	**3776**	**53.41**	25.01	**86.66**	50.58	**118.30**	48.82	**100**	**100**	**100**	**1.15**	**4.27**	**0.81**
Species	**23**	**20**	**25**												

Table A-7. Statistical comparison (t-test) of mean densities of unionids among three sites in Reach 15 of the Upper Mississippi River, 1994-95. Statistically significant differences are denoted by the level of significance and the relationship (> or <) of mean densities.

Reach 15 - 1994-95

Species	Comparison of mean densities between sites		
	Illiniwek:Sylvan	Illiniwek:Case-IH	Case-IH:Sylvan
1. *Actinonaias ligamentina*	NS		
2. *Amblema plicata*	*** >	* >	*** >
3. *Arcidens confragosus*	NS		
4. *Ellipsaria lineolata*	*** >	*** >	*** >
5. *Fusconaia flava*	** >	NS	** >
6. *Lampsilis cardium*	* >	NS	NS
7. *Lampsilis higginsi*	NS	NS	NS
8. *Lasmigona complanata*		NS	
9. *Leptodea fragilis*	*** >	** >	NS
10. *Ligumia recta*	NS	NS	NS
11. *Megalonaias nervosa*	NS	NS	NS
12. *Obliquaria reflexa*	*** >	NS	*** >
13. *Obovaria olivaria*	NS	NS	NS
14. *Potamilus alatus*	NS	NS	NS
15. *Pyganodon grandis*	* >	NS	NS
16. *Quadrula metanevra*	*** <	* <	*** <
17. *Quadrula nodulata*	NS	** <	NS
18. *Quadrula pustulosa*	NS	* <	** >
19. *Quadrula quadrula*	NS	** <	NS
20. *Strophitus undulatus*	NS	NS	NS
21. *Truncilla donaciformis*	*** <	* <	** <
22. *Truncilla truncata*	*** >	*** >	*** >
23. *Utterbackia imbecillis*	NS		

* - significant at p = 0.05 level ** - significant at p = 0.01 level *** - significant at p = 0.001 level

Table A-8. Number, density, relative abundance, and mortality of unionid mussels at Sylvan Slough (RM 485.8) site in Reach 15 of the Upper Mississippi River. These values represent a compilation of all quantitative samples collected at Sylvan Slough (RM 485.8) during 1983, 1985, 1987, and 1994-95 mussel surveys conducted by the Illinois Natural History Survey.

Sylvan Slough (RM 485.8) : 1983, 1985, 1987, and 1994-95

	Number live				Density (no./m²)								Relative abundance (%)				Overall mortality (%)			
					1983		1985		1987		1994-95									
Species	1983	1985	1987	1994-95	Mean	SD	Mean	SD	Mean	SD	Mean	SD	1983	1985	1987	1994-95	1983	1985	1987	1994-95
1. *Actinonaias ligamentina*	0	0	0	3	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.10**	0.64	0.00	0.00	0.00	0.17	0.00	0.00	100.00	0.00
2. *Amblema plicata*	41	78	52	102	**10.20**	1.10	**9.80**	2.60	**6.50**	2.60	**3.25**	4.26	11.45	9.80	5.63	5.95	34.90	22.77	0.00	3.77
3. *Arcidens confragosus*	1	2	0	2	**0.20**	0.40	**0.20**	0.40	**0.00**	0.00	**0.07**	0.53	0.28	0.20	0.00	0.12	0.00	0.00	0.00	0.00
4. *Cumberlandia monodonta*	1	0	0	0	**0.20**	0.40	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5. *Ellipsaria lineolata*	29	42	49	218	**7.20**	3.10	**5.20**	2.80	**6.10**	1.10	**6.80**	5.73	8.10	5.20	5.29	12.71	19.40	6.67	3.92	0.00
6. *Fusconaia flava*	5	4	2	3	**1.20**	0.40	**0.50**	0.50	**0.30**	0.40	**0.10**	0.64	1.40	0.50	0.26	0.17	28.60	20.00	0.00	0.00
7. *Lampsilis cardium*	5	7	5	8	**1.20**	1.10	**0.90**	0.90	**0.60**	0.50	**0.25**	0.96	1.40	0.90	0.52	0.47	16.70	0.00	0.00	0.00
8. *Lampsilis higginsi*	0	0	0	3	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.10**	0.64	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00
9. *Leptodea fragilis*	37	81	82	55	**9.20**	0.80	**10.10**	2.90	**10.30**	3.20	**1.78**	3.22	10.34	10.10	8.93	3.21	9.80	10.99	5.75	0.00
10. *Ligumia recta*	3	2	1	11	**0.80**	1.30	**0.20**	0.40	**0.10**	0.30	**0.28**	0.99	0.84	0.20	0.09	0.64	0.00	33.33	0.00	0.00
11. *Megalonaias nervosa*	33	107	116	66	**8.20**	3.20	**13.40**	4.70	**14.50**	3.80	**2.24**	3.18	9.22	13.40	12.56	3.85	45.00	21.90	1.69	0.00
12. *Obliquaria reflexa*	15	33	39	126	**3.80**	2.40	**4.10**	2.00	**4.90**	2.00	**3.94**	4.03	4.19	4.10	4.25	7.35	31.80	19.51	2.50	2.33
13. *Obovaria olivaria*	0	1	1	1	**0.00**	0.00	**0.10**	0.30	**0.10**	0.30	**0.03**	0.37	0.00	0.10	0.09	0.06	0.00	50.00	0.00	0.00
14. *Plethobasus cyphyus*	0	1	1	10	**0.00**	0.00	**0.10**	0.30	**0.10**	0.30	**0.32**	1.31	0.00	0.10	0.09	0.58	0.00	0.00	0.00	0.00
15. *Potamilus alatus*	16	18	39	4	**4.00**	3.20	**2.20**	0.70	**4.90**	1.60	**0.14**	0.74	4.47	2.20	4.25	0.23	11.10	5.26	0.00	0.00
16. *Potamilus ohiensis*	0	6	7	0	**0.00**	0.00	**0.80**	0.70	**0.90**	0.90	**0.00**	0.00	0.00	0.80	0.78	0.00	0.00	0.00	0.00	0.00
17. *Pyganodon grandis*	5	7	1	3	**1.20**	1.30	**0.90**	0.60	**0.10**	0.30	**0.10**	0.83	1.40	0.90	0.09	0.17	0.00	0.00	0.00	0.00
18. *Quadrula metanevra*	8	53	72	142	**2.00**	1.20	**6.60**	4.10	**9.00**	3.20	**4.42**	5.11	2.23	6.60	7.80	8.28	27.30	1.85	1.37	0.00
19. *Quadrula nodulata*	0	1	4	9	**0.00**	0.00	**0.10**	0.30	**0.50**	0.70	**0.29**	1.27	0.00	0.10	0.43	0.52	100.00	0.00	0.00	0.00
20. *Quadrula pustulosa*	83	158	227	463	**20.80**	5.50	**19.80**	6.20	**28.40**	4.40	**14.15**	9.89	23.18	19.80	24.61	27.00	37.60	25.82	1.73	1.28
21. *Quadrula quadrula*	11	14	10	60	**2.80**	1.50	**1.80**	0.80	**1.30**	1.00	**1.85**	3.58	3.07	1.80	1.13	3.50	15.40	17.65	0.00	0.00
22. *Strophitus undulatus*	0	0	1	1	**0.00**	0.00	**0.00**	0.00	**0.10**	0.30	**0.03**	0.37	0.00	0.00	0.09	0.06	0.00	0.00	0.00	0.00
23. *Truncilla donaciformis*	13	52	51	137	**3.20**	3.30	**6.50**	4.70	**6.40**	3.00	**4.49**	6.50	3.63	6.50	5.55	7.99	27.80	28.77	10.53	2.84
24. *Truncilla truncata*	40	101	158	281	**10.00**	2.30	**12.60**	4.30	**19.80**	7.20	**8.44**	7.29	11.17	12.60	17.16	16.38	33.30	11.40	7.60	1.06
25. *Utterbackia imbecillis*	12	33	4	7	**3.00**	1.00	**4.10**	1.80	**0.50**	1.00	**0.22**	0.90	3.35	4.10	0.43	0.41	7.70	10.81	66.67	0.00
Totals	**358**	**801**	**922**	**1715**	**89.50**	13.50	**100.10**	21.60	**115.40**	17.20	**53.39**	25.01	**100**	**100**	**100**	**100**	**30.40**	**17.93**	**4.46**	**1.15**
Species	**18**	**21**	**21**	**23**																

Table A-9. Statistical comparison (t-test) of mean densities of unionids at Sylvan Slough (RM 485.8) between 1983, 1985, 1987, and 1994-95. Statistically significant differences are denoted by the level of significance and the relationship (> or <) of mean densities.

Sylvan Slough (RM 485.8)

Species	Comparison of mean densities between years					
	1983:1985	1983:1987	1983:1994-95	1985:1987	1985:1994-95	1987:1994-95
1. *Amblema plicata*	NS	* >	** >	* >	*** >	* >
2. *Arcidens confragosus*	NS		NS		NS	
3. *Ellipsaria lineolata*	NS	NS	NS	NS	NS	NS
4. *Fusconaia flava*	* >	** >	*** >	NS	NS	NS
5. *Lampsilis cardium*	NS	NS	NS	NS	NS	NS
6. *Leptodea fragilis*	NS	NS	*** >	NS	*** >	*** >
7. *Ligumia recta*	NS	NS	NS	NS	NS	NS
8. *Megalonaias nervosa*	NS	* <	*** >	NS	*** >	*** >
9. *Obliquaria reflexa*	NS	NS	NS	NS	NS	NS
10. *Potamilus alatus*	NS	NS	*** >	*** <	*** >	*** >
11. *Potamilus ohiensis*				NS	*** >	*** >
12. *Pyganodon grandis*	NS	* >	* >	** >	NS	NS
13. *Quadrula metanevra*	NS	** <	NS	NS	NS	* >
14. *Quadrula nodulata*				NS	NS	NS
15. *Quadrula pustulosa*	NS	* <	NS	** <	NS	*** >
16. *Quadrula quadrula*	NS	NS	NS	NS	NS	NS
17. *Truncilla donaciformis*	NS	NS	NS	NS	NS	NS
18. *Truncilla truncata*	NS	* <	NS	* <	NS	*** >
19. *Utterbackia imbecillis*	NS	** >	*** >	*** >	*** >	NS

NS - not significant * - significant at p = 0.05 level ** - significant at p = 0.01 level *** - significant at p = 0.001 level

Table A-10. Number, density, relative abundance, and mortality of unionid mussels at Case-IH (RM 488.5) site in Reach 15 of the Upper Mississippi River. These values represent a compilation of all quantitative samples collected at Case-IH (RM 488.5) during 1985, 1987, and 1994 mussel surveys conducted by the Illinois Natural History Survey.

Case IH (RM 488.5) : 1985, 1987, and 1994

Species	Number live			Density (no./m²)						Relative abundance (%)			Overall mortality (%)		
				1985		1987		1994							
	1985	1987	1994	Mean	SD	Mean	SD	Mean	SD	1985	1987	1994	1985	1987	1994
1. *Actinonaias ligamentina*	0	1	0	**0.00**	0.00	**0.10**	0.30	**0.00**	0.00	0.00	0.03	0.00	0.00	0.00	0.00
2. *Amblema plicata*	98	325	252	**16.30**	7.30	**40.60**	13.80	**14.00**	12.31	11.74	13.80	15.59	14.80	1.52	6.67
3. *Arcidens confragosus*	2	2	0	**0.30**	0.50	**0.30**	0.40	**0.00**	0.00	0.24	0.10	0.00	0.00	0.00	0.00
4. *Ellipsaria lineolata*	93	262	248	**15.50**	8.00	**32.80**	11.90	**13.78**	15.11	11.14	11.15	15.35	1.10	1.13	1.59
5. *Fusconaia flava*	4	24	11	**0.70**	0.80	**3.00**	1.70	**0.61**	1.72	0.48	1.02	0.68	0.00	0.00	0.00
6. *Lampsilis cardium*	7	11	9	**1.20**	1.10	**1.40**	1.40	**0.50**	1.48	0.84	0.48	0.56	0.00	0.00	0.00
7. *Lampsilis higginsi*	0	1	1	**0.00**	0.00	**0.10**	0.30	**0.06**	0.47	0.00	0.03	0.06	0.00	0.00	0.00
8. *Lasmigona complanata*	0	1	2	**0.00**	0.00	**0.10**	0.30	**0.11**	0.66	0.00	0.03	0.12	0.00	0.00	0.00
9. *Leptodea fragilis*	121	267	37	**20.20**	10.80	**33.40**	15.40	**2.06**	3.66	14.49	11.35	2.29	4.70	3.96	5.13
10. *Ligumia recta*	2	8	2	**0.30**	0.50	**1.00**	0.70	**0.11**	0.66	0.24	0.34	0.12	0.00	0.00	0.00
11. *Megalonaias nervosa*	16	15	65	**2.70**	2.20	**1.90**	1.50	**3.61**	6.52	1.92	0.65	4.02	27.30	0.00	0.00
12. *Obliquaria reflexa*	25	115	165	**4.20**	2.00	**14.40**	6.10	**9.17**	9.45	2.99	0.37	10.21	3.80	0.00	1.20
13. *Obovaria olivaria*	2	9	2	**0.30**	0.50	**1.10**	1.30	**0.11**	0.66	0.24	4.89	0.12	0.00	0.00	0.00
14. *Potamilus alatus*	37	105	3	**6.20**	4.70	**13.10**	6.60	**0.17**	0.80	4.43	4.45	0.19	0.00	0.94	57.14
15. *Potamilus ohiensis*	4	16	0	**0.70**	1.10	**2.00**	1.90	**0.00**	0.00	0.48	0.68	0.00	0.00	11.11	0.00
16. *Pyganodon grandis*	0	1	7	**0.00**	0.00	**0.10**	0.30	**0.39**	1.36	0.00	0.03	0.43	0.00	0.00	0.00
17. *Quadrula metanevra*	2	7	15	**0.30**	0.50	**0.90**	0.90	**0.83**	2.00	0.24	0.31	0.93	0.00	0.00	0.00
18. *Quadrula nodulata*	3	24	11	**0.50**	0.50	**3.00**	2.20	**0.61**	1.72	0.36	1.02	0.68	0.00	4.00	0.00
19. *Quadrula pustulosa*	136	489	378	**22.70**	14.80	**61.10**	26.10	**21.00**	19.44	16.29	20.76	23.39	7.50	1.01	2.33
20. *Quadrula quadrula*	17	44	47	**2.80**	2.00	**5.50**	2.40	**2.61**	3.73	2.04	1.87	2.91	5.60	0.00	4.08
21. *Strophitus undulatus*	0	0	1	**0.00**	0.00	**0.00**	0.00	**0.06**	0.47	0.00	0.00	0.06	0.00	0.00	0.00
22. *Truncilla donaciformis*	44	67	36	**7.30**	4.30	**8.40**	9.10	**2.00**	3.84	5.27	2.85	2.23	21.40	8.22	14.29
23. *Truncilla truncata*	206	559	324	**34.30**	15.20	**69.90**	43.30	**18.00**	11.43	24.67	23.75	20.05	0.50	1.76	7.16
24. *Utterbackia imbecillis*	16	1	0	**2.70**	4.00	**0.10**	0.30	**0.00**	0.00	1.92	0.03	0.00	0.00	50.00	0.00
Totals	**835**	**2354**	**1616**	**139.20**	62.10	**294.30**	94.30	**89.79**	25.01	**100**	**100**	**100**	**6.30**	**1.88**	**4.27**
Species	**19**	**23**	**20**												

Table A-11. Statistical comparison (t-test) of mean densities of unionids at Case-IH (RM 488.5) between 1985, 1987, and 1994. Statistically significant differences are denoted by the level of significance and the relationship (> or <) of mean densities.

Case-IH (RM 488.5)

Species	Comparison of mean densities between years		
	1985:1987	1985:1994	1987:1994
1. *Amblema plicata*	** <	NS	*** >
2. *Ellipsaria lineolata*	** <	NS	** >
3. *Fusconaia flava*	* <	NS	** >
4. *Lampsilis cardium*	NS	NS	NS
5. *Lampsilis higginsi*			NS
6. *Lasmigona complanata*			NS
7. *Leptodea fragilis*	NS	*** >	*** >
8. *Ligumia recta*	NS	NS	** >
9. *Megalonaias nervosa*	NS	NS	NS
10. *Obliquaria reflexa*	** <	NS	NS
11. *Obovaria olivaria*	NS	NS	** >
12. *Potamilus alatus*	NS	*** >	*** >
13. *Potamilus ohiensis*	NS		
14. *Pyganodon grandis*		NS	NS
15. *Quadrula metanevra*	NS	NS	NS
16. *Quadrula nodulata*	* <	NS	** >
17. *Quadrula pustulosa*	** <	NS	*** >
18. *Quadrula quadrula*	* <	NS	* >
19. *Truncilla donaciformis*	NS	** >	** >
20. *Truncilla truncata*	NS	** >	*** >
21. *Utterbackia imbecillis*	NS		

* - significant at p = 0.05 level ** - significant at p = 0.01 level *** - significant at p = 0.001 level

Table A-12. Statistical comparison (t-test) of mean densities of unionids at Reach 15 (UMR) between sites and years (1983 to 1995). Statistically significant differences are denoted by the level of significance and the relationship (> or <) of mean densities.

Reach 15 Sites : 1983 to 1995

Comparison of mean densities between sites and years		
Site	**Variables**	**Significance**
Reach 15, 1994-95	Illiniwek : Sylvan Slough	*** >
Reach 15, 1994-95	Illiniwek : Case-IH	*** >
Reach 15, 1994-95	Case-IH : Sylvan Slough	*** >
Reach 15, 1987	Case-IH : Sylvan Slough	*** >
Reach 15, 1985	Case-IH : Sylvan Slough	NS
Sylvan Slough (RM 485.8)	1983 : 1985	NS
Sylvan Slough (RM 485.8)	1983 : 1987	* <
Sylvan Slough (RM 485.8)	1983 : 1994-95	** >
Sylvan Slough (RM 485.8)	1985 : 1987	NS
Sylvan Slough (RM 485.8)	1985 : 1994-95	*** >
Sylvan Slough (RM 485.8)	1987 : 1994-95	*** >
Case-IH (RM 488.5)	1985 : 1987	** <
Case-IH (RM 488.5)	1985 : 1994	*** >
Case-IH (RM 488.5)	1987 : 1994	*** >

* - significant at p = 0.05 level ** - significant at p = 0.01 level *** - significant at p = 0.001 level

Appendix B

Calculated number of samples required to estimate actual density within specified level (%)

Reach 15 of the Upper Mississippi River

Appendix B

Calculated number of samples required to estimate actual density within specified level (%)

Reach 15 of the Upper Mississippi River

Table B-1. Calculated number of quantitative samples required to estimate unionid density at three sites in Reach 15 (UMR) within x% of the actual density with a 0.05% probability of being incorrect. Based on the formula : $n = [(2SD) \div (xM)]^2$, where : n = number of samples required, SD = standard deviation, x = desired level of accuracy (i.e., 10% = 0.1), and M = mean unionid density based on samples collected. Numbers within rectangles indicate the number of samples collected met or exceeded the number of samples required for each level of accuracy (%).

Reach 15 (UMR)

Site	Date	Density		Samples	Samples Required				
		Mean	SD	Collected	10%	20%	30%	40%	50%
Sylvan Slough (RM 485.8)	June 1994	**48.2**	20.8	80	74	19	8	5	3
	June 1995	**68.9**	30.3	30	77	19	9	5	3
	Sept. 1995	**45.0**	15.0	6	44	11	5	3	2
	Overall 94-95	**53.4**	25.0	116	88	22	10	5	4
	1983	**89.5**	13.5	4	9	2	1	1	0
	1985	**100.1**	21.6	8	19	5	2	1	1
	1987	**115.4**	17.2	8	9	2	1	1	0
	1985-87	**107.8**	10.8	16	4	1	0	0	0
Case-IH (RM 488.5)	June 1994	**97.0**	51.1	50	111	28	12	7	4
	Aug. 1994	**63.2**	41.1	22	169	42	19	11	7
	Overall 1994	**86.7**	50.6	72	136	34	15	9	5
	1985	**139.3**	62.1	6	79	20	9	5	3
	1987	**294.3**	94.3	8	41	10	5	3	2
	1985-87	**216.8**	109.6	14	102	26	11	6	4
Illiniwek (RM 492.4)	June 1994	**150.7**	42.7	40	32	8	4	2	1
	Aug. 1994	**124.5**	41.4	22	44	11	5	3	2
	June 1995	**82.7**	34.2	30	68	17	8	4	3
	Sept. 1995	**83.7**	15.3	6	13	3	1	1	1
	Overall 94-95	**118.3**	48.8	98	68	17	8	4	3

Table B-2. Calculated number of quantitative samples required to estimate unionid species density at Sylvan Slough (RM 485.8) in (a) 1994-95 (116 samples collected) and (b) 1985 (8 samples collected) within x% of the actual density with a 0.05% probability of being incorrect. Based on the formula : $n = [(2\ SD) \div (xM)]^2$, where : n = number of samples required, SD = standard deviation, x = desired level of accuracy (i.e., 10% = 0.1), and M = mean unionid density based on samples collected. Numbers within rectangles indicate the number of samples collected met or exceeded the number of samples required for each level of accuracy (%).

(a) 1994-95 (116 samples)	Density (/m²)		Samples Required				
Species	Mean	SD	10%	20%	30%	40%	50%
Quadrula pustulosa	**14.15**	9.89	195	49	22	12	8
Ellipsaria lineolata	**6.80**	5.73	284	71	32	18	11
Truncilla truncata	**8.44**	7.29	298	75	33	19	12
Obliquaria reflexa	**3.94**	4.03	418	105	46	26	17
Quadrula metanevra	**4.42**	5.11	535	134	59	33	21
Amblema plicata	**3.25**	4.26	687	172	76	43	27
Megalonaias nervosa	**2.24**	3.18	806	202	90	50	32
Truncilla donaciformis	**4.49**	6.50	838	210	93	52	34
Leptodea fragilis	**1.78**	3.22	1309	327	145	82	52
Quadrula quadrula	**1.85**	3.58	1498	374	166	94	60
Ligumia recta	**0.28**	0.99	5001	1250	556	313	200
Lampsilis cardium	**0.25**	0.96	5898	1475	655	369	236
Utterbackia imbecillis	**0.22**	0.90	6694	1674	744	418	268
Plethobasus cyphyus	**0.32**	1.31	6704	1676	745	419	268
Quadrula nodulata	**0.29**	1.27	7671	1918	852	479	307
Potamilus alatus	**0.14**	0.74	11176	2794	1242	698	447
Actinonaias ligamentina	**0.10**	0.64	16384	4096	1820	1024	655
Lampsilis higginsi	**0.10**	0.64	16384	4096	1820	1024	655
Fusconaia flava	**0.10**	0.64	16384	4096	1820	1024	655
Arcidens confragosus	**0.07**	0.53	22931	5733	2548	1433	917
Pyganodon grandis	**0.10**	0.83	27556	6889	3062	1722	1102
Strophitus undulatus	**0.03**	0.37	60844	15211	6760	3803	2434
Obovaria olivaria	**0.03**	0.37	60844	15211	6760	3803	2434

(b) 1985 (8 samples)	Density (/m²)		Samples Required				
Species	Mean	SD	10%	20%	30%	40%	50%
Amblema plicata	**9.80**	2.60	28	7	3	2	1
Leptodea fragilis	**10.10**	2.90	33	8	4	2	1
Quadrula pustulosa	**19.80**	6.20	39	10	4	2	2
Potamilus alatus	**2.20**	0.70	40	10	4	3	2
Truncilla truncata	**12.60**	4.30	47	12	5	3	2
Megalonaias nervosa	**13.40**	4.70	49	12	5	3	2
Utterbackia imbecillis	**4.10**	1.80	77	19	9	5	3
Quadrula quadrula	**1.80**	0.80	79	20	9	5	3
Obliquaria reflexa	**4.10**	2.00	95	24	11	6	4
Ellipsaria lineolata	**5.20**	2.80	116	29	13	7	5
Quadrula metanevra	**6.60**	4.10	154	39	17	10	6
Pyganodon grandis	**0.90**	0.60	178	44	20	11	7
Truncilla donaciformis	**6.50**	4.70	209	52	23	13	8
Potamilus ohiensis	**0.80**	0.70	306	77	34	19	12
Fusconaia flava	**0.50**	0.50	400	100	44	25	16
Lampsilis cardium	**0.90**	0.90	400	100	44	25	16
Ligumia recta	**0.20**	0.40	1600	400	178	100	64
Arcidens confragosus	**0.20**	0.40	1600	400	178	100	64
Quadrula nodulata	**0.10**	0.30	3600	900	400	225	144
Obovaria olivaria	**0.10**	0.30	3600	900	400	225	144
Plethobasus cyphyus	**0.10**	0.30	3600	900	400	225	144

Table B-3. Calculated number of quantitative samples required to estimate unionid species density at Case-IH (RM 488.5) in (a) 1994 (72 samples collected) and (b) 1985 (6 samples collected) within x% of the actual density with a 0.05% probability of being incorrect. Based on the formula : $n = [(2\ SD) \div (xM)]^2$, where : n = number of samples required, SD = standard deviation, x = desired level of accuracy (i.e., 10% = 0.1), and M = mean unionid density based on samples collected. Numbers within rectangles indicate the number of samples collected met or exceeded the number of samples required for each level of accuracy (%).

(a) 1994 (72 samples)	Density (/m²)		Samples Required				
Species	Mean	SD	10%	20%	30%	40%	50%
Truncilla truncata	**18.00**	11.43	161	40	18	10	6
Amblema plicata	**14.00**	12.31	309	77	34	19	12
Quadrula pustulosa	**21.00**	19.44	343	86	38	21	14
Obliquaria reflexa	**9.17**	9.45	425	106	47	27	17
Ellipsaria lineolata	**13.78**	15.11	481	120	53	30	19
Quadrula quadrula	**2.61**	3.73	817	204	91	51	33
Leptodea fragilis	**2.06**	3.66	1263	316	140	79	51
Megalonaias nervosa	**3.61**	6.52	1305	326	145	82	52
Truncilla donaciformis	**2.00**	3.84	1475	369	164	92	59
Quadrula metanevra	**0.83**	2.00	2323	581	258	145	93
Quadrula nodulata	**0.61**	1.72	3180	795	353	199	127
Fusconaia flava	**0.61**	1.72	3180	795	353	199	127
Lampsilis cardium	**0.50**	1.48	3505	876	389	219	140
Pyganodon grandis	**0.39**	1.36	4864	1216	540	304	195
Potamilus alatus	**0.17**	0.80	8858	2215	984	554	354
Ligumia recta	**0.11**	0.66	14400	3600	1600	900	576
Lasmigona complanata	**0.11**	0.66	14400	3600	1600	900	576
Obovaria olivaria	**0.11**	0.66	14400	3600	1600	900	576
Strophitus undulatus	**0.06**	0.47	24544	6136	2727	1534	982
Lampsilis higginsi	**0.06**	0.47	24544	6136	2727	1534	982

(b) 1985 (6 samples)	Density (/m²)		Samples Required				
Species	Mean	SD	10%	20%	30%	40%	50%
Truncilla truncata	**34.30**	15.20	79	20	9	5	3
Amblema plicata	**16.30**	7.30	80	20	9	5	3
Obliquaria reflexa	**4.20**	2.00	91	23	10	6	4
Ellipsaria lineolata	**15.50**	8.00	107	27	12	7	4
Leptodea fragilis	**20.20**	10.80	114	29	13	7	5
Truncilla donaciformis	**7.30**	4.30	139	35	15	9	6
Quadrula pustulosa	**22.70**	14.80	170	43	19	11	7
Quadrula quadrula	**2.80**	2.00	204	51	23	13	8
Potamilus alatus	**6.20**	4.70	230	57	26	14	9
Megalonaias nervosa	**2.70**	2.20	266	66	30	17	11
Lampsilis cardium	**1.20**	1.10	336	84	37	21	13
Quadrula nodulata	**0.50**	0.50	400	100	44	25	16
Fusconaia flava	**0.70**	0.80	522	131	58	33	21
Utterbackia imbecillis	**2.70**	4.00	878	219	98	55	35
Potamilus ohiensis	**0.70**	1.10	988	247	110	62	40
Quadrula metanevra	**0.30**	0.50	1111	278	123	69	44
Arcidens confragosus	**0.30**	0.50	1111	278	123	69	44
Ligumia recta	**0.30**	0.50	1111	278	123	69	44
Obovaria olivaria	**0.30**	0.50	1111	278	123	69	44

Table B-4. Calculated number of quantitative samples required to estimate unionid species density at Illiniwek (RM 492.4) in 1994-95 (98 samples collected) within x% of the actual density with a 0.05% probability of being incorrect. Based on the formula : $n = [(2\ SD) \div (xM)]^2$, where : n = number of samples required, SD = standard deviation, x = desired level of accuracy (i.e., 10% = 0.1), and M = mean unionid density based on samples collected. Numbers within rectangles indicate the number of samples collected met or exceeded the number of samples required for each level of accuracy (%).

(a) 1994 (98 samples)

Species	Density (/m²)		Samples Required				
	Mean	SD	10%	20%	30%	40%	50%
Ellipsaria lineolata	**35.02**	18.14	107	27	12	7	4
Truncilla truncata	**35.59**	21.26	143	36	16	9	6
Amblema plicata	**10.34**	7.51	211	53	23	13	8
Quadrula pustulosa	**16.17**	12.11	224	56	25	14	9
Obliquaria reflexa	**9.93**	8.60	300	75	33	19	12
Leptodea fragilis	**3.83**	4.36	518	130	58	32	21
Megalonaias nervosa	**2.77**	3.16	521	130	58	33	21
Quadrula quadrula	**1.33**	2.19	1085	271	121	68	43
Truncilla donaciformis	**1.02**	1.99	1523	381	169	95	61
Lampsilis cardium	**0.63**	1.45	2119	530	235	132	85
Fusconaia flava	**0.51**	1.44	3189	797	354	199	128
Pyganodon grandis	**0.50**	1.65	4356	1089	484	272	174
Potamilus alatus	**0.34**	1.24	5320	1330	591	333	213
Utterbackia imbecillis	**0.42**	1.55	5448	1362	605	340	218
Quadrula metanevra	**0.33**	1.24	5648	1412	628	353	226
Ligumia recta	**0.24**	0.96	6400	1600	711	400	256
Arcidens confragosus	**0.20**	0.89	7921	1980	880	495	317
Lasmigona complanata	**0.16**	0.80	10000	2500	1111	625	400
Lampsilis higginsi	**0.13**	0.70	11598	2899	1289	725	464
Obovaria olivaria	**0.13**	0.70	11598	2899	1289	725	464
Strophitus undulatus	**0.09**	0.58	16612	4153	1846	1038	664
Actinonaias ligamentina	**0.12**	0.90	22500	5625	2500	1406	900
Quadrula nodulata	**0.05**	0.42	28224	7056	3136	1764	1129
Potamilus ohiensis	**0.04**	0.40	40000	10000	4444	2500	1600
Cumberlandia monodonta	**0.04**	0.40	40000	10000	4444	2500	1600

Appendix C

Density distributions based on shell length

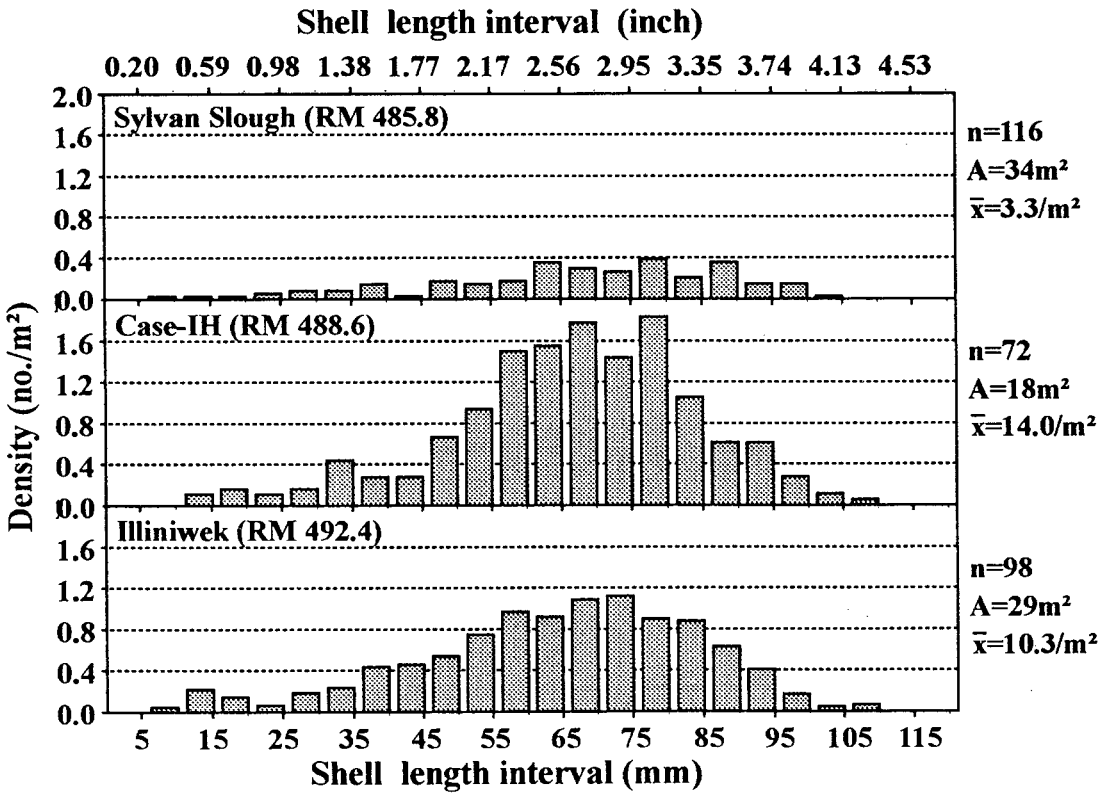
Pool 15 of the Upper Mississippi River

Part I.

Density distributions for unionid species from Sylvan Slough (RM 485.8), Case-IH (RM 488.6), and Illiniwek (RM 492.4), 1994-95.

Figure C-1. Density distribution based on shell length of *Amblema plicata* (Threeridge) from three sites in Reach 15 of the Upper Mississippi River, 1994-95.

Species : *Amblema plicata*
Site : Reach 15 (UMR)
Year : 1994-95

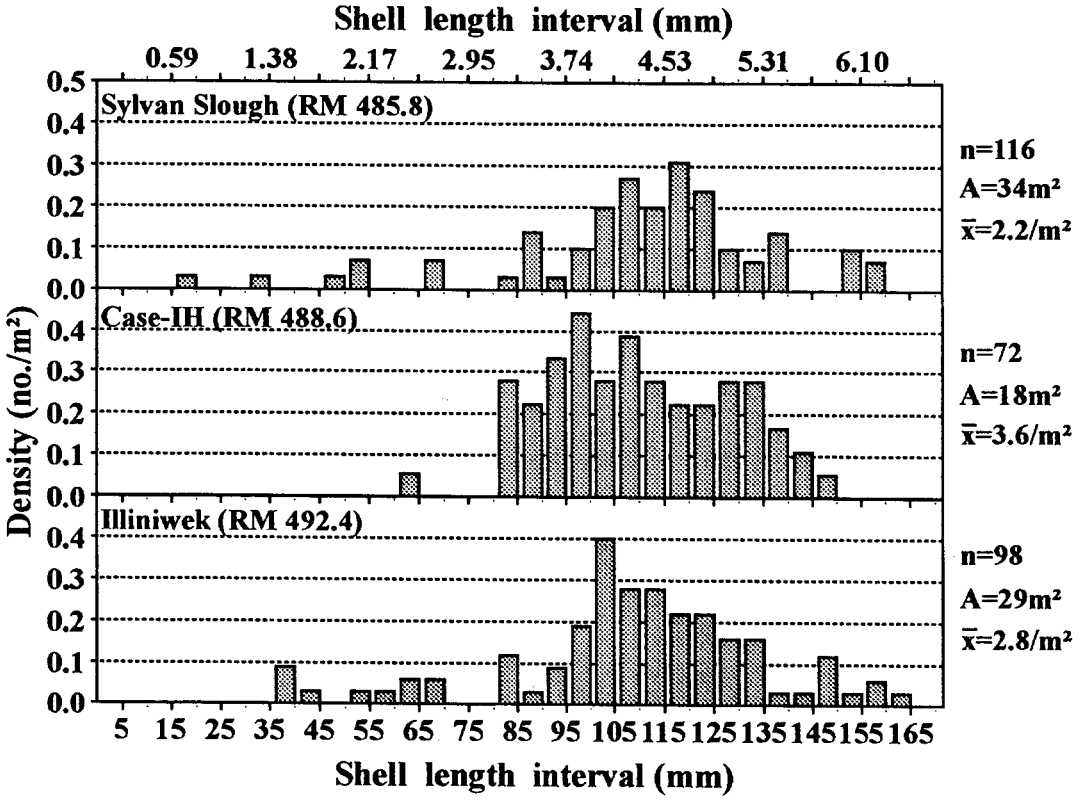


Length Interval (mm)	Density (no./m²) Sylvan	Case-IH	Illiniwek	Length Interval (inch)
5	0	0	0	*0.20*
10	0.03	0	0.05	*0.39*
15	0.03	0.11	0.22	*0.59*
20	0.03	0.17	0.15	*0.79*
25	0.06	0.11	0.07	*0.98*
30	0.09	0.17	0.19	*1.18*
35	0.09	0.44	0.24	*1.38*
40	0.15	0.28	0.44	*1.57*
45	0.03	0.28	0.46	*1.77*
50	0.18	0.67	0.54	*1.97*
55	0.15	0.94	0.75	*2.17*
60	0.18	1.50	0.97	*2.36*
65	0.36	1.56	0.92	*2.56*
70	0.30	1.78	1.09	*2.76*
75	0.27	1.44	1.12	*2.95*
80	0.39	1.83	0.90	*3.15*
85	0.21	1.06	0.88	*3.35*
90	0.36	0.61	0.63	*3.54*
95	0.15	0.61	0.41	*3.74*
100	0.15	0.28	0.17	*3.94*
105	0.03	0.11	0.05	*4.13*
110	0	0.06	0.07	*4.33*
115	0	0	0	*4.53*
120	0	0	0	*4.72*
Mean Density	**3.24**	**14.00**	**10.34**	

n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.

Figure C-2. Density distribution based on shell length of *Megalonaias nervosa* (Washboard) from three sites in Reach 15 of the Upper Mississippi River, 1994-95.

Species : *Megalonaias nervosa*
Site : Reach 15 (UMR)
Year : 1994-95



n=116
A=34m²
$\bar{x}$=2.2/m²

n=72
A=18m²
$\bar{x}$=3.6/m²

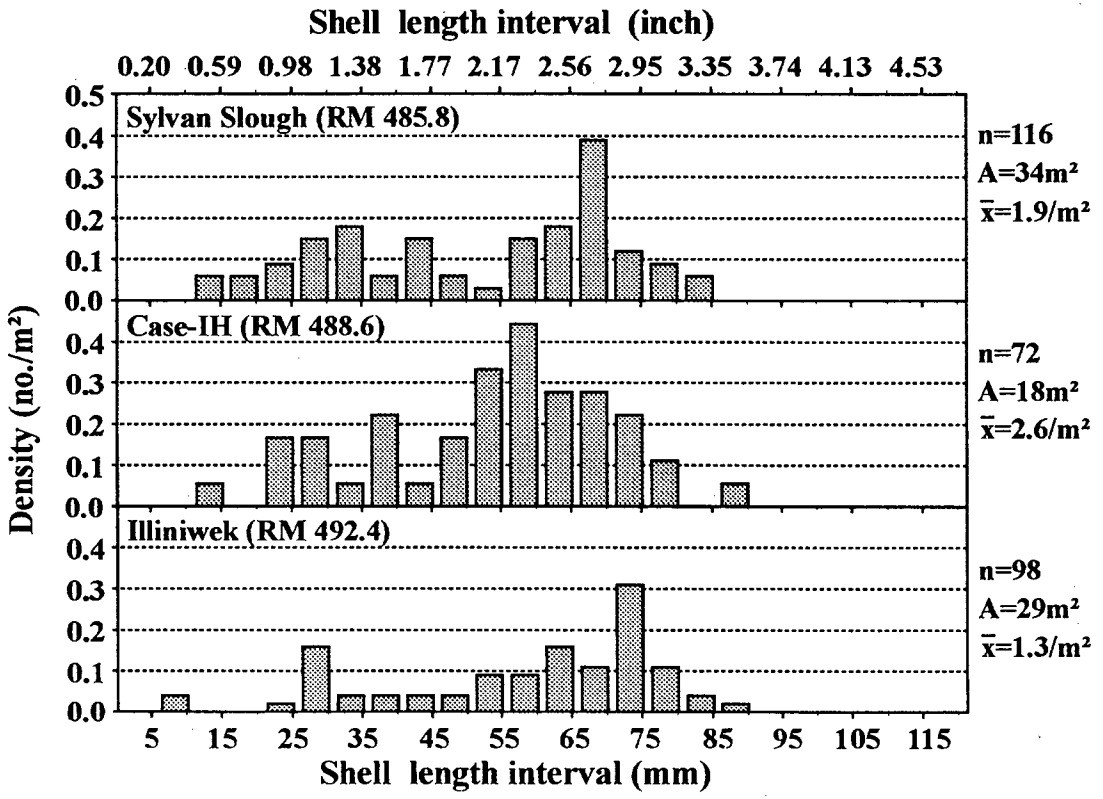
n=98
A=29m²
$\bar{x}$=2.8/m²

n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.

Length Interval (mm)	Density (no./m²) Sylvan	Case-IH	Illiniwek	Length Interval (inch)
5	0	0	0	0.20
10	0	0	0	0.39
15	0	0	0	0.59
20	0.03	0	0	0.79
25	0.00	0	0	0.98
30	0.00	0	0	1.18
35	0.03	0	0	1.38
40	0.00	0	0.09	1.57
45	0.00	0	0.03	1.77
50	0.03	0	0.00	1.97
55	0.07	0	0.03	2.17
60	0.00	0	0.03	2.36
65	0.00	0.06	0.06	2.56
70	0.07	0.00	0.06	2.76
75	0.00	0.00	0.00	2.95
80	0.00	0.00	0.00	3.15
85	0.03	0.28	0.12	3.35
90	0.14	0.22	0.03	3.54
95	0.03	0.33	0.09	3.74
100	0.10	0.44	0.19	3.94
105	0.20	0.28	0.40	4.13
110	0.27	0.39	0.28	4.33
115	0.20	0.28	0.28	4.53
120	0.31	0.22	0.22	4.72
125	0.24	0.22	0.22	4.92
130	0.10	0.28	0.16	5.12
135	0.07	0.28	0.16	5.31
140	0.14	0.17	0.03	5.51
145	0.00	0.11	0.03	5.71
150	0.00	0.06	0.12	5.91
155	0.10	0	0.03	6.10
160	0.07	0	0.06	6.30
165	0	0	0.03	6.50
170	0	0	0	6.69
Mean Density	**2.24**	**3.61**	**2.77**	

Figure C-3. Density distribution based on shell length of *Quadrula quadrula* (Mapleleaf) from three sites in Reach 15 of the Upper Mississippi River, 1994-95.

Species : *Quadrula quadrula*
Site : Reach 15 (UMR)
Year : 1994-95

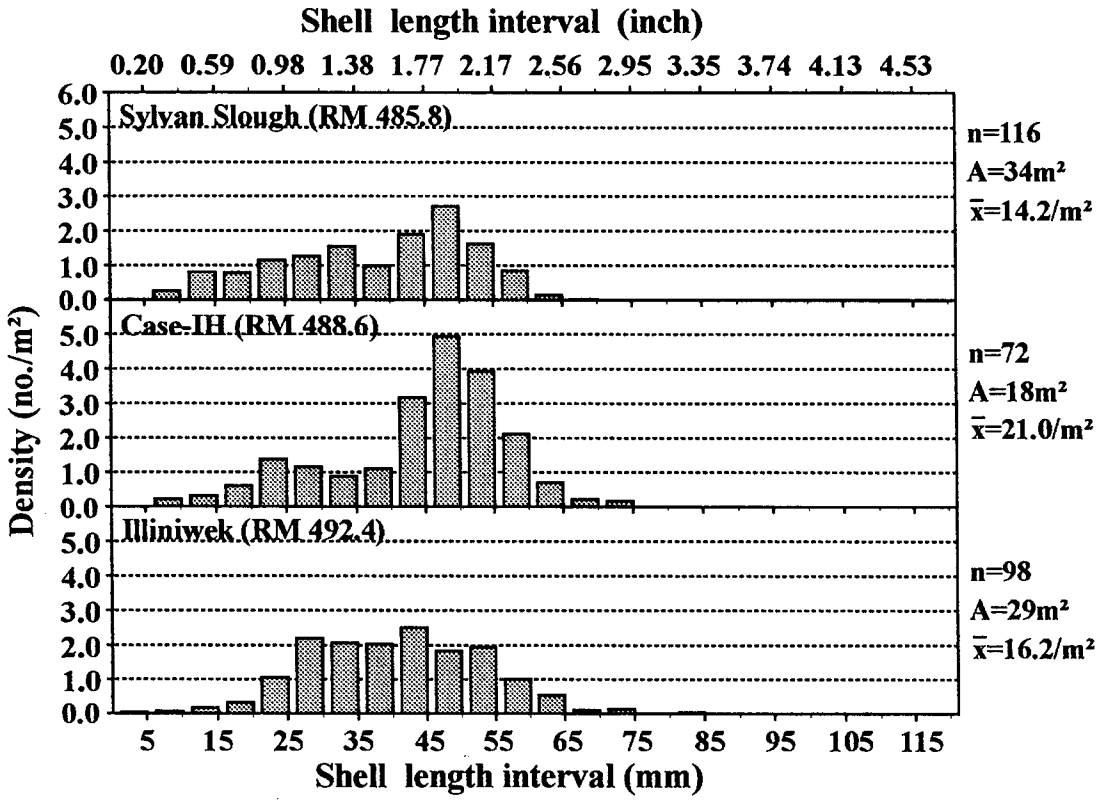


Length Interval (mm)	Density (no./m²) Sylvan	Case-IH	Illiniwek	Length Interval (inch)
5	0	0	0	0.20
10	0	0	0.04	0.39
15	0.06	0.06	0.00	0.59
20	0.06	0.00	0.00	0.79
25	0.09	0.17	0.02	0.98
30	0.15	0.17	0.16	1.18
35	0.18	0.06	0.04	1.38
40	0.06	0.22	0.04	1.57
45	0.15	0.06	0.04	1.77
50	0.06	0.17	0.04	1.97
55	0.03	0.33	0.09	2.17
60	0.15	0.44	0.09	2.36
65	0.18	0.28	0.16	2.56
70	0.39	0.28	0.11	2.76
75	0.12	0.22	0.31	2.95
80	0.09	0.11	0.11	3.15
85	0.06	0.00	0.04	3.35
90	0	0.06	0.02	3.54
95	0	0	0	3.74
100	0	0	0	3.94
105	0	0	0	4.13
110	0	0	0	4.33
115	0	0	0	4.53
120	0	0	0	4.72
Mean Density	1.85	2.61	1.33	

n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.

Figure C-4. Density distribution based on shell length of *Quadrula pustulosa* (Pimpleback) from three sites in Reach 15 of the Upper Mississippi River, 1994-95.

Species : *Quadrula pustulosa*
Site : Reach 15 (UMR)
Year : 1994-95

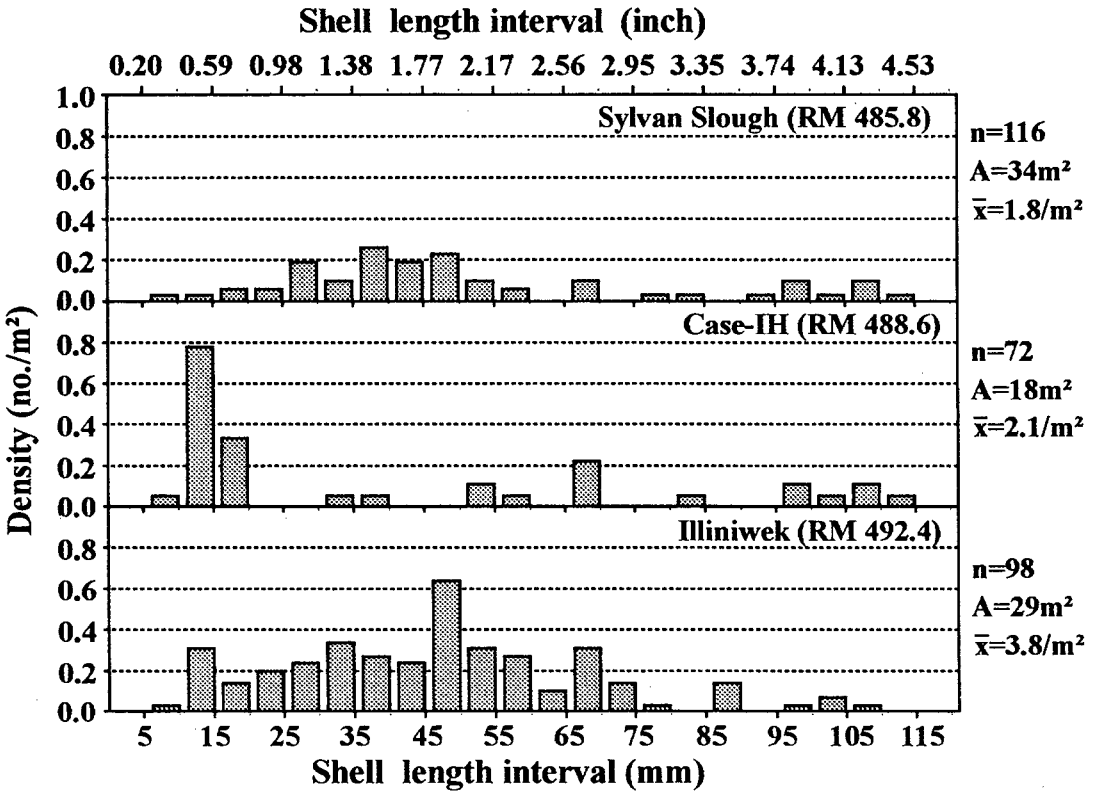


Length Interval (mm)	Density (no./m²) Sylvan	Case-IH	Illiniwek	Length Interval (inch)
5	0	0	0.04	0.20
10	0.27	0.22	0.07	0.39
15	0.82	0.33	0.18	0.59
20	0.79	0.61	0.33	0.79
25	1.15	1.39	1.07	0.98
30	1.27	1.17	2.21	1.18
35	1.57	0.89	2.06	1.38
40	1.00	1.11	2.03	1.57
45	1.90	3.17	2.50	1.77
50	2.72	4.94	1.84	1.97
55	1.63	3.94	1.95	2.17
60	0.85	2.11	1.03	2.36
65	0.15	0.72	0.55	2.56
70	0.03	0.22	0.11	2.76
75	0	0.17	0.15	2.95
80	0	0	0.00	3.15
85	0	0	0.04	3.35
90	0	0	0	3.54
95	0	0	0	3.74
100	0	0	0	3.94
105	0	0	0	4.13
110	0	0	0	4.33
115	0	0	0	4.53
120	0	0	0	4.72
Mean Density	**14.15**	**21.00**	**16.17**	

n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.

Figure C-5. Density distribution based on shell length of *Leptodea fragilis* (Fragile papershell) from three sites in Reach 15 of the Upper Mississippi River, 1994-95.

Species : *Leptodea fragilis*
Site : Reach 15 (UMR)
Year : 1994-95

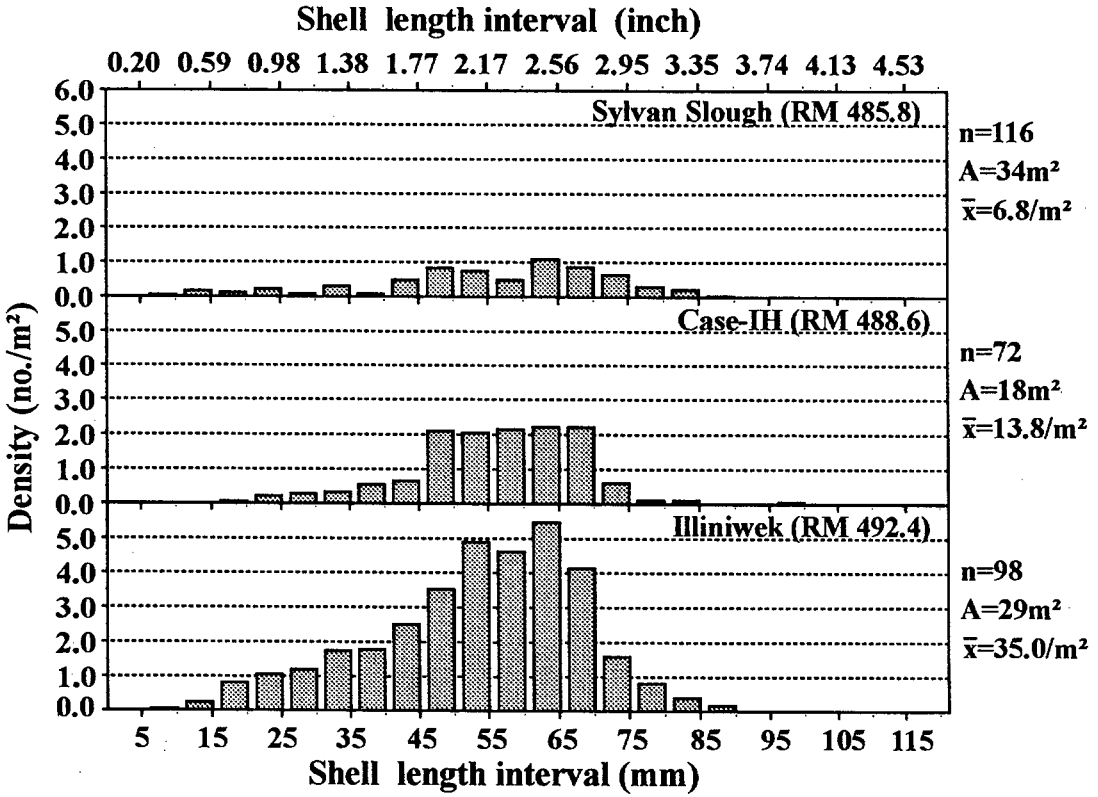


Length Interval (mm)	Density (no./m²) Sylvan	Case-IH	Illiniwek	Length Interval (inch)
5	0	0	0	0.20
10	0.03	0.06	0.03	0.39
15	0.03	0.78	0.31	0.59
20	0.06	0.33	0.14	0.79
25	0.06	0.00	0.20	0.98
30	0.19	0.00	0.24	1.18
35	0.10	0.06	0.34	1.38
40	0.26	0.06	0.27	1.57
45	0.19	0.00	0.24	1.77
50	0.23	0.00	0.64	1.97
55	0.10	0.11	0.31	2.17
60	0.06	0.06	0.27	2.36
65	0.00	0.00	0.10	2.56
70	0.10	0.22	0.31	2.76
75	0.00	0.00	0.14	2.95
80	0.03	0.00	0.03	3.15
85	0.03	0.06	0.00	3.35
90	0.00	0.00	0.14	3.54
95	0.03	0.00	0.00	3.74
100	0.10	0.11	0.03	3.94
105	0.03	0.06	0.07	4.13
110	0.10	0.11	0.03	4.33
115	0.03	0.06	0	4.53
120	0	0	0	4.72
Mean Density	1.78	2.06	3.83	

n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.

Figure C-6. Density distribution based on shell length of *Ellipsaria lineolata* (Butterfly) from three sites in Reach 15 of the Upper Mississippi River, 1994-95.

Species : *Ellipsaria lineolata*
Site : Reach 15 (UMR)
Year : 1994-95

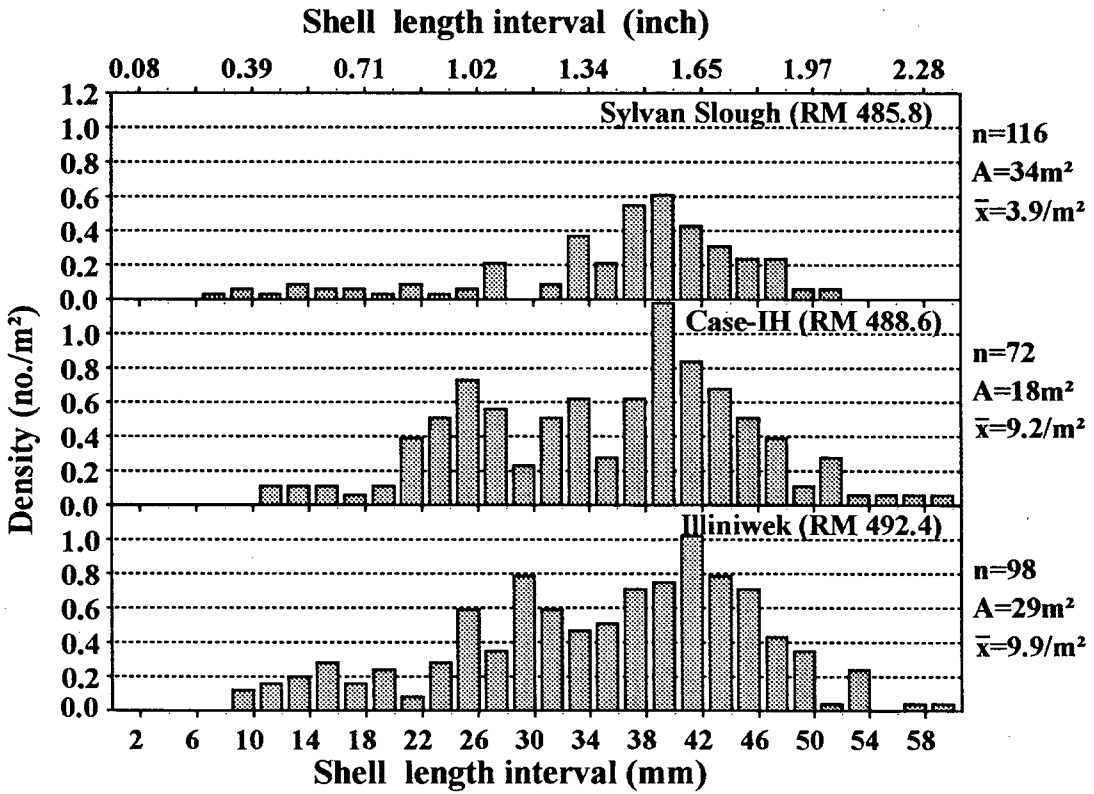


Length Interval (mm)	Density (no./m²) Sylvan	Case-IH	Illiniwek	Length Interval (inch)
5	0	0	0	0.20
10	0.06	0	0.04	0.39
15	0.16	0	0.23	0.59
20	0.12	0.06	0.82	0.79
25	0.22	0.22	1.05	0.98
30	0.09	0.28	1.20	1.18
35	0.31	0.33	1.75	1.38
40	0.09	0.56	1.79	1.57
45	0.50	0.67	2.52	1.77
50	0.84	2.11	3.53	1.97
55	0.75	2.06	4.89	2.17
60	0.50	2.17	4.62	2.36
65	1.09	2.22	5.47	2.56
70	0.87	2.22	4.15	2.76
75	0.65	0.61	1.59	2.95
80	0.31	0.11	0.82	3.15
85	0.22	0.11	0.39	3.35
90	0.03	0.00	0.16	3.54
95	0	0.00	0	3.74
100	0	0.06	0	3.94
105	0	0	0	4.13
110	0	0	0	4.33
115	0	0	0	4.53
120	0	0	0	4.72
Mean Density	**6.80**	**13.78**	**35.02**	

n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.

Figure C-7. Density distribution based on shell length of *Obliquaria reflexa* (Threehorn) from three sites inReachl 15 of the Upper Mississippi River, 1994-95.

Species : *Obliquaria reflexa*
Site : Reach 15 (UMR)
Year : 1994-95

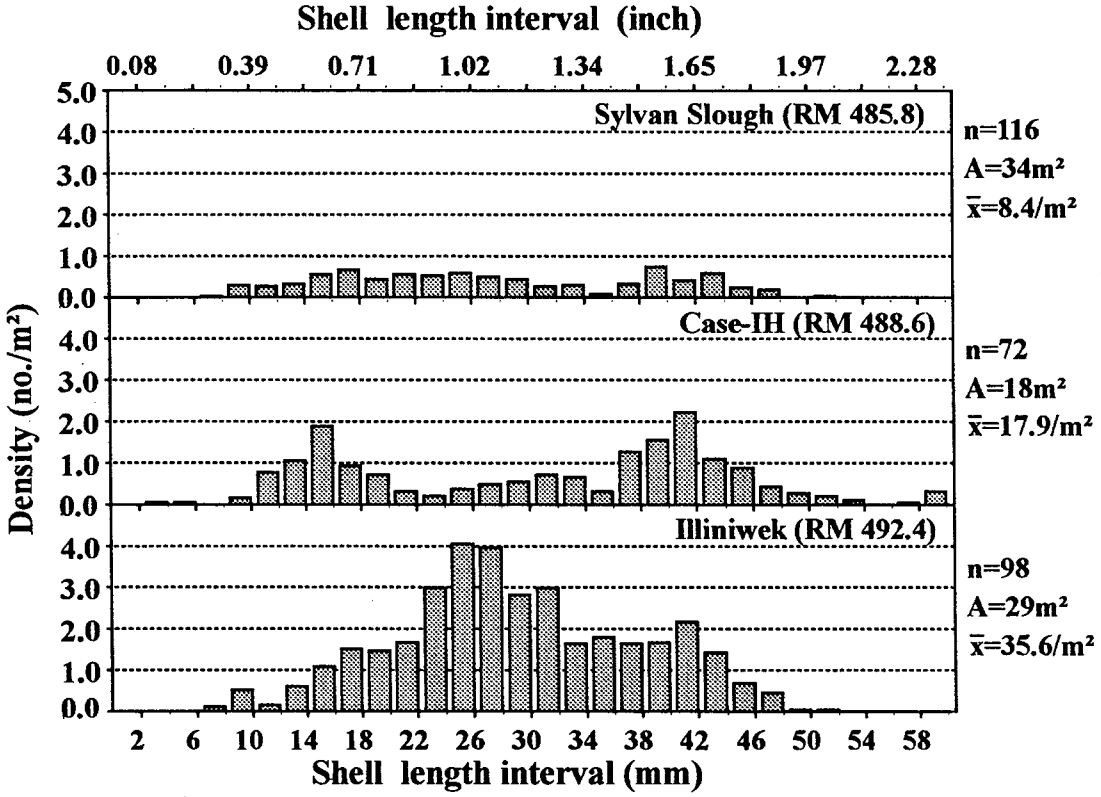


n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.

Length Interval (mm)	Density (no./m²) Sylvan	Case-IH	Illiniwek	Length Interval (inch)
2	0	0	0	0.08
4	0	0	0	0.16
6	0	0	0	0.24
8	0.03	0	0	0.31
10	0.06	0	0.12	0.39
12	0.03	0.11	0.16	0.47
14	0.09	0.11	0.20	0.55
16	0.06	0.11	0.28	0.63
18	0.06	0.06	0.16	0.71
20	0.03	0.11	0.24	0.79
22	0.09	0.39	0.08	0.87
24	0.03	0.51	0.28	0.94
26	0.06	0.73	0.59	1.02
28	0.21	0.56	0.35	1.10
30	0.00	0.23	0.79	1.18
32	0.09	0.51	0.59	1.26
34	0.37	0.62	0.47	1.34
36	0.21	0.28	0.51	1.42
38	0.55	0.62	0.71	1.50
40	0.61	1.18	0.75	1.57
42	0.43	0.84	1.02	1.65
44	0.31	0.68	0.79	1.73
46	0.24	0.51	0.71	1.81
48	0.24	0.39	0.43	1.89
50	0.06	0.11	0.35	1.97
52	0.06	0.28	0.04	2.05
54	0	0.06	0.24	2.13
56	0	0.06	0.00	2.20
58	0	0.06	0.04	2.28
60	0	0.06	0.04	2.36
Mean Density	3.94	9.17	9.93	

Figure C-8. Density distribution based on shell length of *Truncilla truncata* (Deertoe) from three sites in Reach 15 of the Upper Mississippi River, 1994-95.

Species : *Truncilla truncata*
Site : Reach 15 (UMR)
Year : 1994-95

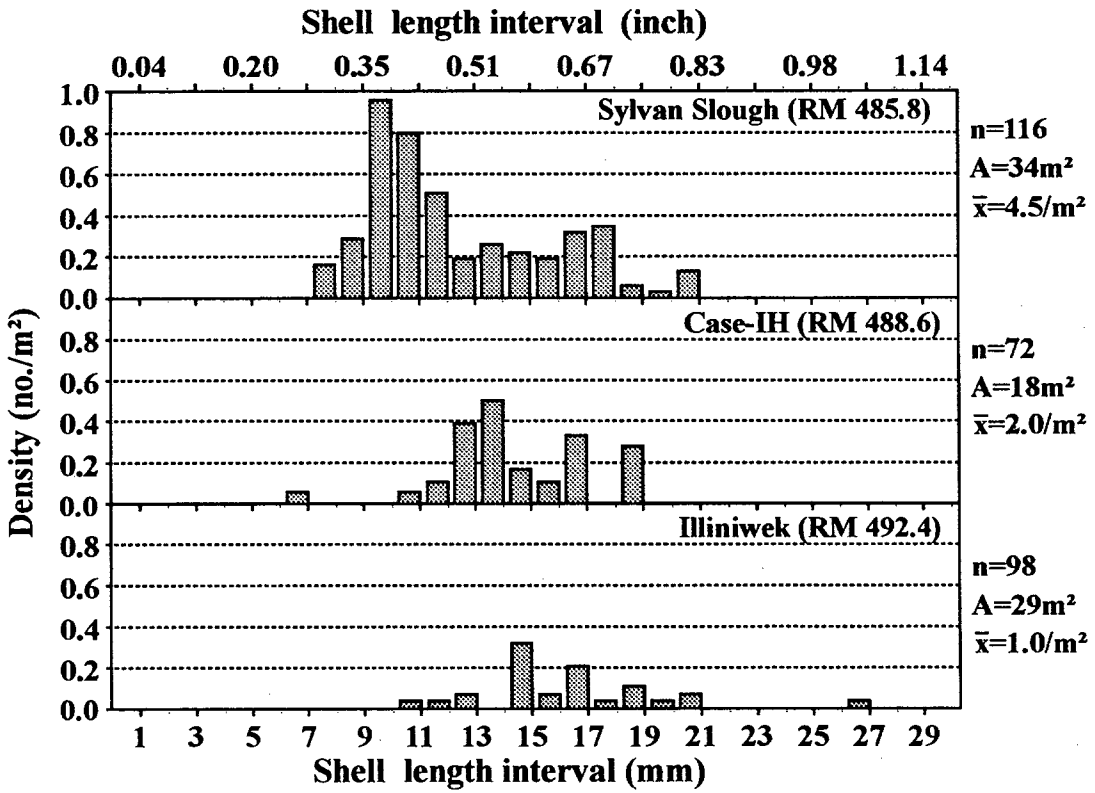


n = number of quantitative samples collected.
A = Total area (m²) of n quantitative samples.
x̄ = mean density from n quantitative samples.

Length Interval (mm)	Density (no./m²) Sylvan	Case-IH	Illiniwek	Length Interval (inch)
2	0	0	0	0.08
4	0	0.06	0	0.16
6	0	0.06	0	0.24
8	0.03	0.00	0.12	0.31
10	0.30	0.17	0.53	0.39
12	0.27	0.78	0.16	0.47
14	0.33	1.06	0.61	0.55
16	0.56	1.89	1.10	0.63
18	0.68	0.94	1.51	0.71
20	0.45	0.72	1.47	0.79
22	0.56	0.33	1.68	0.87
24	0.53	0.22	2.99	0.94
26	0.59	0.39	4.05	1.02
28	0.51	0.50	3.97	1.10
30	0.45	0.56	2.82	1.18
32	0.27	0.72	2.99	1.26
34	0.30	0.67	1.64	1.34
36	0.09	0.33	1.80	1.42
38	0.33	1.28	1.64	1.50
40	0.74	1.56	1.68	1.57
42	0.42	2.22	2.17	1.65
44	0.59	1.11	1.43	1.73
46	0.24	0.89	0.70	1.81
48	0.18	0.44	0.45	1.89
50	0.00	0.28	0.04	1.97
52	0.03	0.22	0.04	2.05
54	0	0.11	0	2.13
56	0	0.00	0	2.20
58	0	0.06	0	2.28
60	0	0.33	0	2.36
Mean Density	8.44	17.89	35.59	

Figure C-9. Density distribution based on shell length of *Truncilla donaciformis* (Fawnsfoot) from three sites in Reachl 15 of the Upper Mississippi River, 1994-95.

Species : *Truncilla donaciformis*
Site : Reach 15 (UMR)
Year : 1994-95



n = number of quantitative samples collected.
A = Total area (m²) of n quantitative samples.
x̄ = mean density from n quantitative samples.

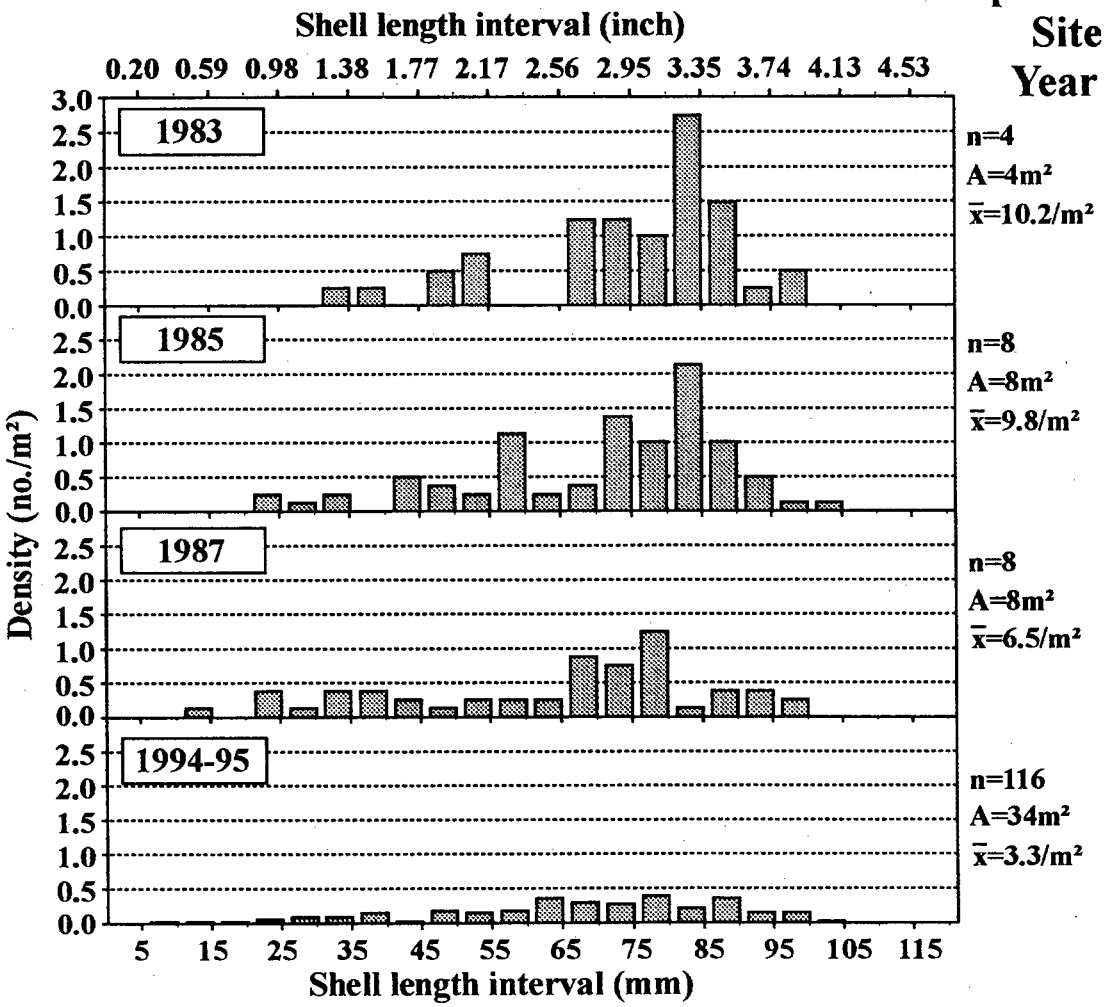
Length Interval (mm)	Density (no./m²) Sylvan	Case-IH	Illiniwek	Length Interval (inch)
1	0	0	0	0.04
2	0	0	0	0.08
3	0	0	0	0.12
4	0	0	0	0.16
5	0	0	0	0.20
6	0	0	0	0.24
7	0	0.06	0	0.28
8	0.16	0.00	0	0.31
9	0.29	0.00	0	0.35
10	0.96	0.00	0	0.39
11	0.80	0.06	0.04	0.43
12	0.51	0.11	0.04	0.47
13	0.19	0.39	0.07	0.51
14	0.26	0.50	0.00	0.55
15	0.22	0.17	0.32	0.59
16	0.19	0.11	0.07	0.63
17	0.32	0.33	0.21	0.67
18	0.35	0.00	0.04	0.71
19	0.06	0.28	0.11	0.75
20	0.03	0	0.04	0.79
21	0.13	0	0.07	0.83
22	0	0	0.00	0.87
23	0	0	0.00	0.91
24	0	0	0.00	0.94
25	0	0	0.00	0.98
26	0	0	0.00	1.02
27	0	0	0.04	1.06
28	0	0	0	1.10
29	0	0	0	1.14
30	0	0	0	1.18
31	0	0	0	1.22
32	0	0	0	1.26
33	0	0	0	1.30
34	0	0	0	1.34
35	0	0	0	1.38
Mean Density	4.49	2.00	1.02	

Part II.

Density distributions for unionid species at Sylvan Slough (RM 485.8) from 1983, 1985, 1987, and 1995.

Figure C-10. Density distribution based on shell length of *Amblema plicata* (Threeridge) from Sylvan Slough site (RM 485.8) in Reach 15 of the Upper Mississippi River, 1983, 1985, 1987, and 1994-95.

Species : *Amblema plicata*
Site : Sylvan Slough (RM 485.8)
Year : 1983, 1985, 1987, and 1994-95

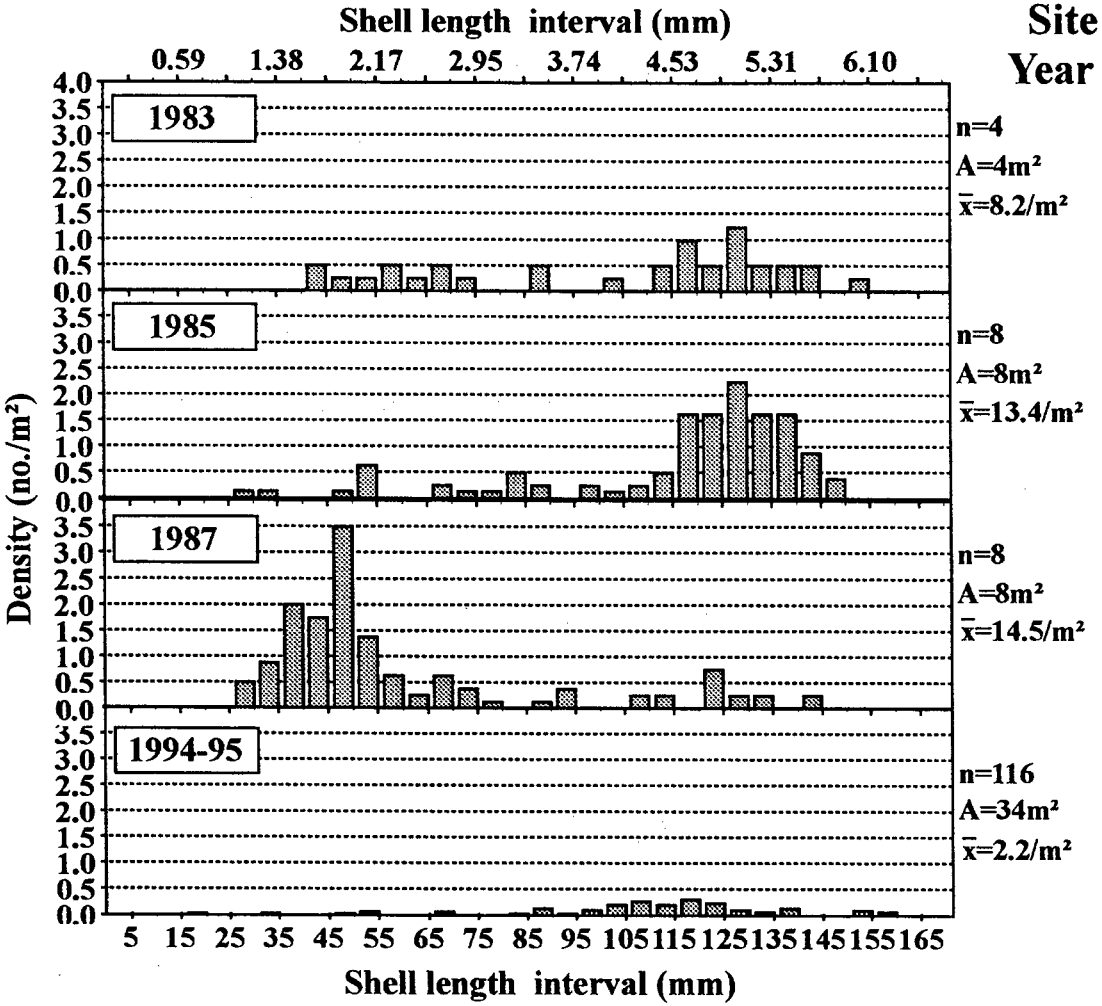


Length Interval (mm)	Density (no./m²) 1983	1985	1987	1994-95	Length Interval (inch)
5	0	0	0	0	0.20
10	0	0	0	0.03	0.39
15	0	0	0.13	0.03	0.59
20	0	0	0.00	0.03	0.79
25	0.00	0.25	0.38	0.06	0.98
30	0.00	0.13	0.13	0.09	1.18
35	0.25	0.25	0.38	0.09	1.38
40	0.25	0.00	0.38	0.15	1.57
45	0.00	0.50	0.25	0.03	1.77
50	0.50	0.38	0.13	0.18	1.97
55	0.75	0.25	0.25	0.15	2.17
60	0.00	1.13	0.25	0.18	2.36
65	0.00	0.25	0.25	0.36	2.56
70	1.24	0.38	0.88	0.30	2.76
75	1.24	1.38	0.75	0.27	2.95
80	1.00	1.01	1.25	0.39	3.15
85	2.74	2.14	0.13	0.21	3.35
90	1.49	1.01	0.38	0.36	3.54
95	0.25	0.50	0.38	0.15	3.74
100	0.50	0.13	0.25	0.15	3.94
105	0	0.13	0	0.03	4.13
110	0	0	0	0	4.33
115	0	0	0	0	4.53
120	0	0	0	0	4.72
Mean Density	10.20	9.80	6.50	3.24	

n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.

Figure C-11. Density distribution based on shell length of *Megalonaias nervosa* (Washboard) from Sylvan Slough site (RM 485.8) in Reach 15 of the Upper Mississippi River, 1983, 1985, 1987, and 1994-95.

Species : *Megalonaias nervosa*
Site : Sylvan Slough (RM 485.8)
Year : 1983, 1985, 1987, and 1994-95

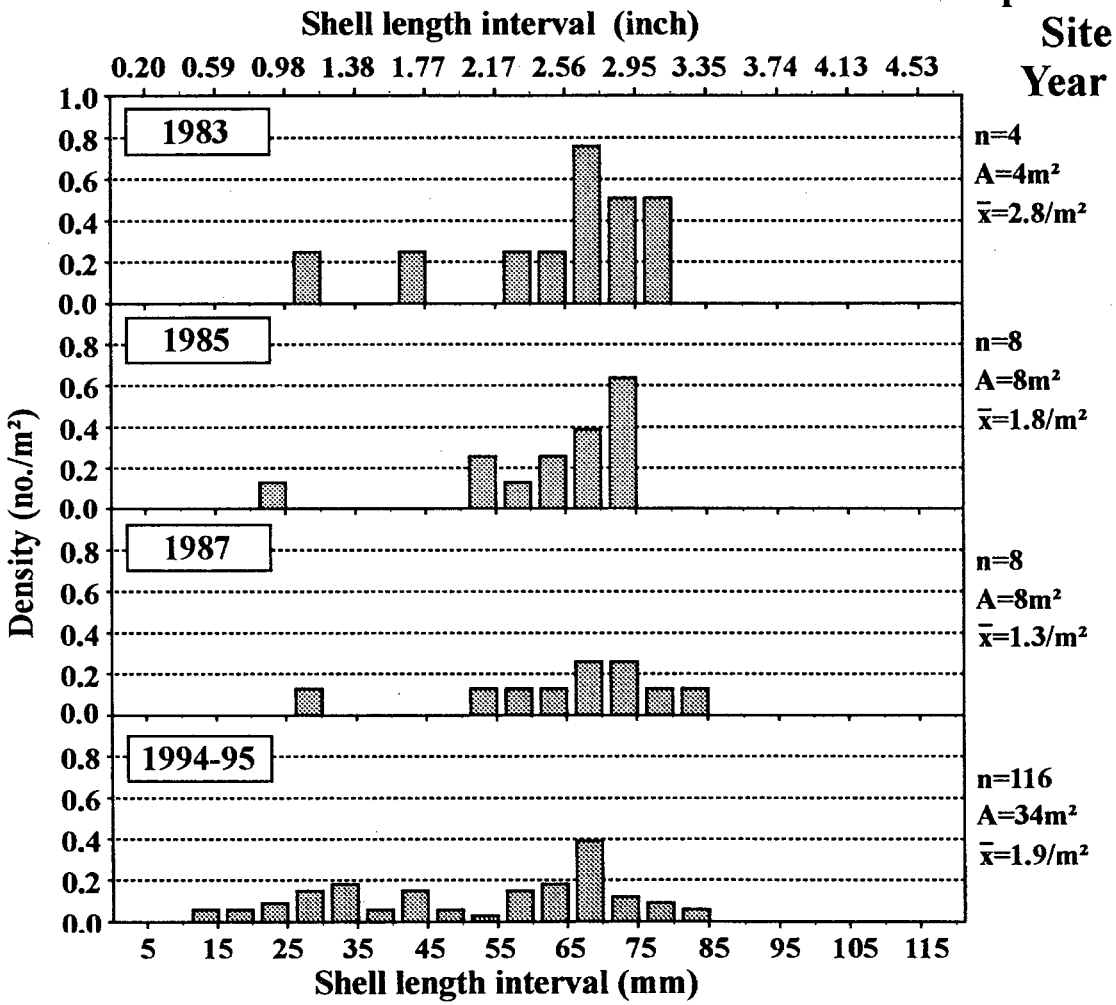


n = number of quantitative samples collected.
A = Total area (m²) of n quantitative samples.
x̄ = mean density from n quantitative samples.

Length Interval (mm)	Density (no./m²) 1983	1985	1987	1994-95	Length Interval (inch)
5	0	0	0	0	0.20
10	0	0	0	0	0.39
15	0	0	0	0	0.59
20	0	0	0	0.03	0.79
25	0	0	0	0.00	0.98
30	0.00	0.13	0.50	0.00	1.18
35	0.00	0.13	0.88	0.03	1.38
40	0.00	0.00	2.00	0.00	1.57
45	0.50	0.00	1.75	0.00	1.77
50	0.25	0.13	3.50	0.03	1.97
55	0.25	0.63	1.38	0.07	2.17
60	0.50	0.00	0.63	0.00	2.36
65	0.25	0.00	0.25	0.00	2.56
70	0.50	0.25	0.63	0.07	2.76
75	0.25	0.13	0.38	0.00	2.95
80	0.00	0.13	0.13	0.00	3.15
85	0.00	0.50	0.00	0.03	3.35
90	0.50	0.25	0.13	0.14	3.54
95	0.00	0.00	0.38	0.03	3.74
100	0.00	0.25	0.00	0.10	3.94
105	0.25	0.13	0.00	0.20	4.13
110	0.00	0.25	0.25	0.27	4.33
115	0.50	0.50	0.25	0.20	4.53
120	0.99	1.63	0.00	0.31	4.72
125	0.50	1.63	0.75	0.24	4.92
130	1.24	2.25	0.25	0.10	5.12
135	0.50	1.63	0.25	0.07	5.31
140	0.50	1.63	0.00	0.14	5.51
145	0.50	0.88	0.25	0.00	5.71
150	0.00	0.38	0	0.00	5.91
155	0.25	0	0	0.10	6.10
160	0	0	0	0.07	6.30
165	0	0	0	0	6.50
170	0	0	0	0	6.69
Mean Density	8.20	13.40	14.50	2.24	

Figure C-12. Density distribution based on shell length of *Quadrula quadrula* (Mapleleaf) from Sylvan Slough site (RM 485.8) in Reachl 15 of the Upper Mississippi River, 1983, 1985, 1987, and 1994-95.

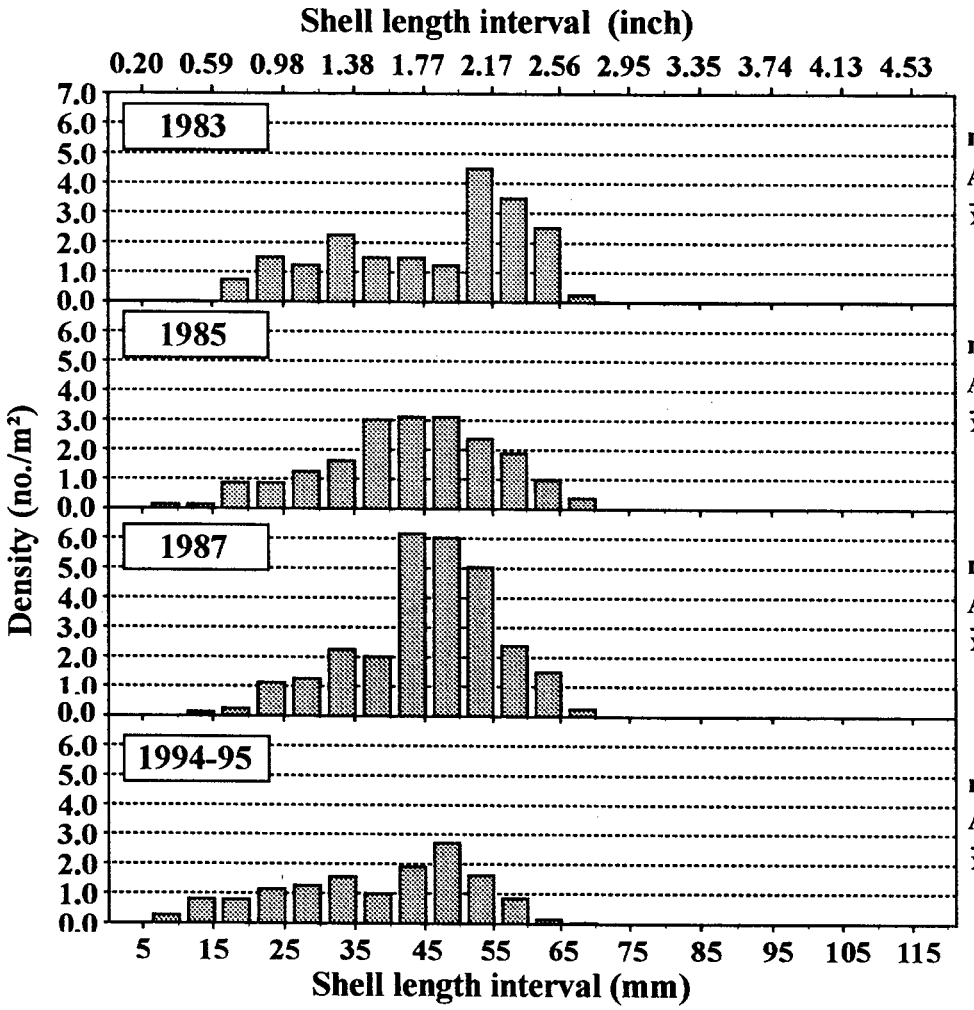
Species : *Quadrula quadrula*
Site : Sylvan Slough (RM 485.8)
Year : 1983, 1985, 1987, and 1994-95



Length Interval (mm)	Density (no./m²) 1983	1985	1987	1994-95	Length Interval (inch)
5	0	0	0	0	0.20
10	0	0	0	0	0.39
15	0	0	0	0.06	0.59
20	0	0	0	0.06	0.79
25	0	0.13	0	0.09	0.98
30	0.25	0.00	0.13	0.15	1.18
35	0.00	0.00	0.00	0.18	1.38
40	0.00	0.00	0.00	0.06	1.57
45	0.25	0.00	0.00	0.15	1.77
50	0.00	0.00	0.00	0.06	1.97
55	0.00	0.26	0.13	0.03	2.17
60	0.25	0.13	0.13	0.15	2.36
65	0.25	0.26	0.13	0.18	2.56
70	0.76	0.39	0.26	0.39	2.76
75	0.51	0.64	0.26	0.12	2.95
80	0.51	0	0.13	0.09	3.15
85	0	0	0.13	0.06	3.35
90	0	0	0	0	3.54
95	0	0	0	0	3.74
100	0	0	0	0	3.94
105	0	0	0	0	4.13
110	0	0	0	0	4.33
115	0	0	0	0	4.53
120	0	0	0	0	4.72
Mean Density	2.80	1.80	1.30	1.85	

n = number of quantitative samples collected.
A = Total area (m^2) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.

Figure C-13. Density distribution based on shell length of *Quadrula pustulosa* (Pimpleback) from Sylvan Slough site (RM 485.8) in Reach 15 of the Upper Mississippi River, 1983, 1985, 1987, and 1994-95.



Species : *Quadrula pustulosa*
Site : Sylvan Slough (RM 485.8)
Year : 1983, 1985, 1987, and 1994-95

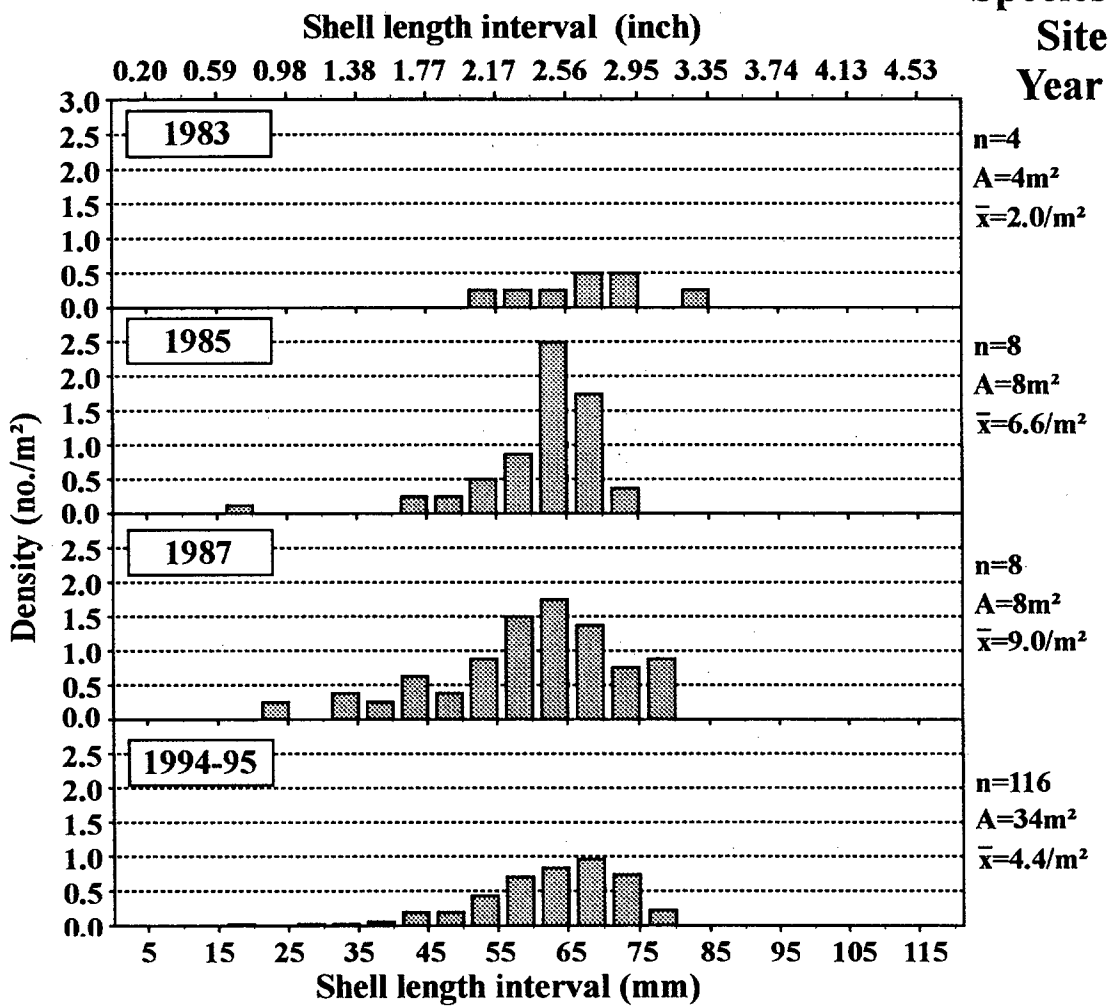
1983: n=4, A=4m², $\bar{x}$=20.8/m²
1985: n=8, A=8m², $\bar{x}$=19.8/m²
1987: n=8, A=8m², $\bar{x}$=28.4/m²
1994-95: n=116, A=34m², $\bar{x}$=14.2/m²

Length Interval (mm)	Density (no./m²) 1983	1985	1987	1994-95	Length Interval (inch)
5	0	0	0	0	0.20
10	0	0.13	0	0.27	0.39
15	0.00	0.13	0.13	0.82	0.59
20	0.75	0.88	0.25	0.79	0.79
25	1.50	0.88	1.13	1.15	0.98
30	1.25	1.25	1.26	1.27	1.18
35	2.26	1.63	2.26	1.57	1.38
40	1.50	3.01	2.01	1.00	1.57
45	1.50	3.13	6.16	1.90	1.77
50	1.25	3.13	6.03	2.72	1.97
55	4.51	2.38	5.03	1.63	2.17
60	3.51	1.88	2.39	0.85	2.36
65	2.51	1.00	1.51	0.15	2.56
70	0.25	0.38	0.25	0.03	2.76
75	0	0	0	0	2.95
80	0	0	0	0	3.15
85	0	0	0	0	3.35
90	0	0	0	0	3.54
95	0	0	0	0	3.74
100	0	0	0	0	3.94
105	0	0	0	0	4.13
110	0	0	0	0	4.33
115	0	0	0	0	4.53
120	0	0	0	0	4.72
Mean Density	20.80	19.80	28.40	14.15	

n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.

Figure C-14. Density distribution based on shell length of *Quadrula metanevra* (Monkeyface) from Sylvan Slough site (RM 485.8) in Reach 15 of the Upper Mississippi River, 1983, 1985, 1987, and 1994-95.

Species : *Quadrula metanevra*
Site : Sylvan Slough (RM 485.8)
Year : 1983, 1985, 1987, and 1994-95

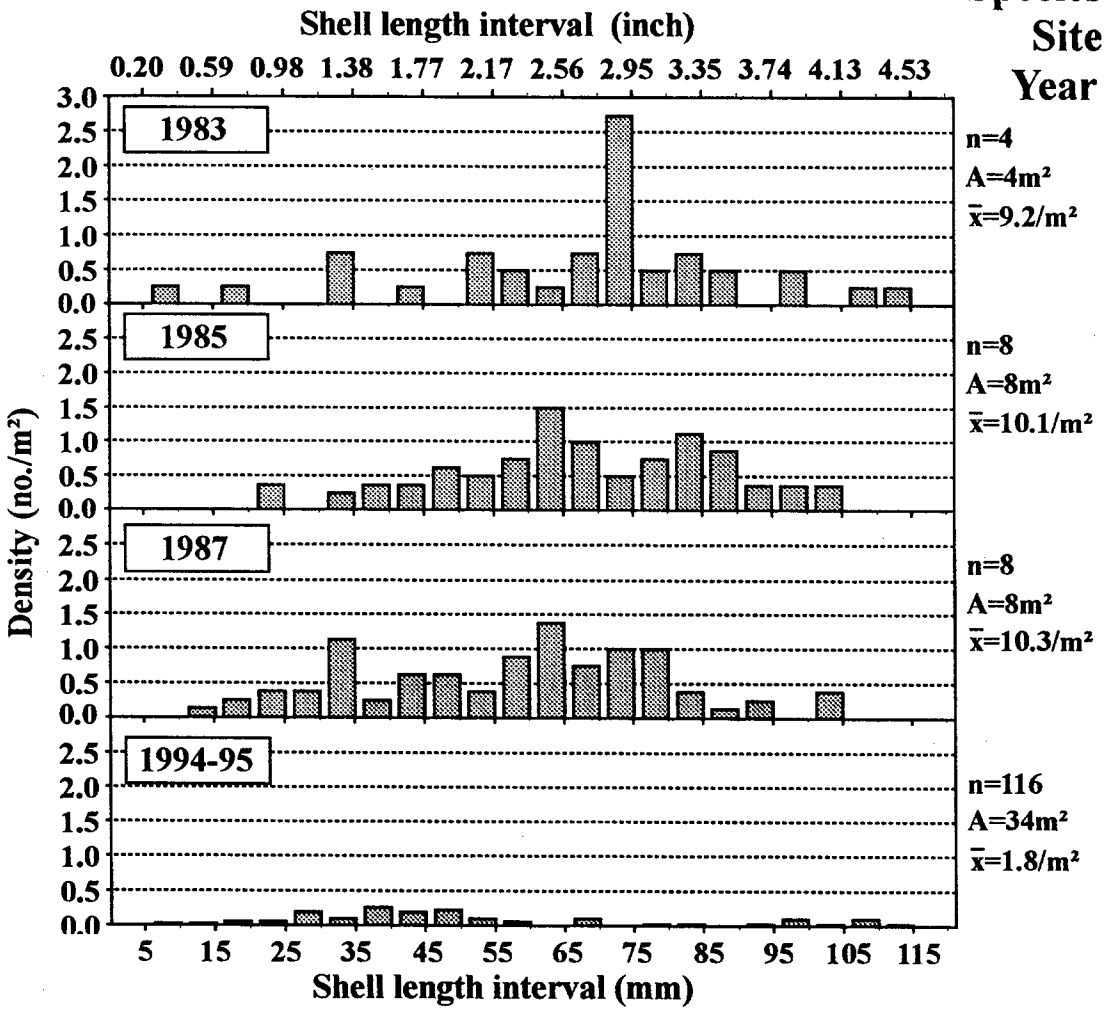


Length Interval (mm)	Density (no./m²) 1983	1985	1987	1994-95	Length Interval (inch)
5	0	0	0	0	0.20
10	0	0	0	0	0.39
15	0	0	0	0	0.59
20	0	0.12	0	0.03	0.79
25	0	0.00	0.25	0.00	0.98
30	0	0.00	0.00	0.03	1.18
35	0	0.00	0.38	0.03	1.38
40	0	0.00	0.25	0.06	1.57
45	0	0.25	0.63	0.19	1.77
50	0	0.25	0.38	0.19	1.97
55	0.25	0.50	0.88	0.43	2.17
60	0.25	0.87	1.50	0.71	2.36
65	0.25	2.49	1.75	0.83	2.56
70	0.50	1.74	1.38	0.96	2.76
75	0.50	0.37	0.75	0.74	2.95
80	0.00	0	0.88	0.22	3.15
85	0.25	0	0	0	3.35
90	0	0	0	0	3.54
95	0	0	0	0	3.74
100	0	0	0	0	3.94
105	0	0	0	0	4.13
110	0	0	0	0	4.33
115	0	0	0	0	4.53
120	0	0	0	0	4.72
Mean Density	2.00	6.60	9.00	4.42	

n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.

Figure C-15. Density distribution based on shell length of *Leptodea fragilis* (Fragile papershell) from Sylvan Slough site (RM 485.8) in Reach 15 of the Upper Mississippi River, 1983, 1985, 1987, and 1994-95.

Species : *Leptodea fragilis*
Site : Sylvan Slough (RM 485.8)
Year : 1983, 1985, 1987, and 1994-95

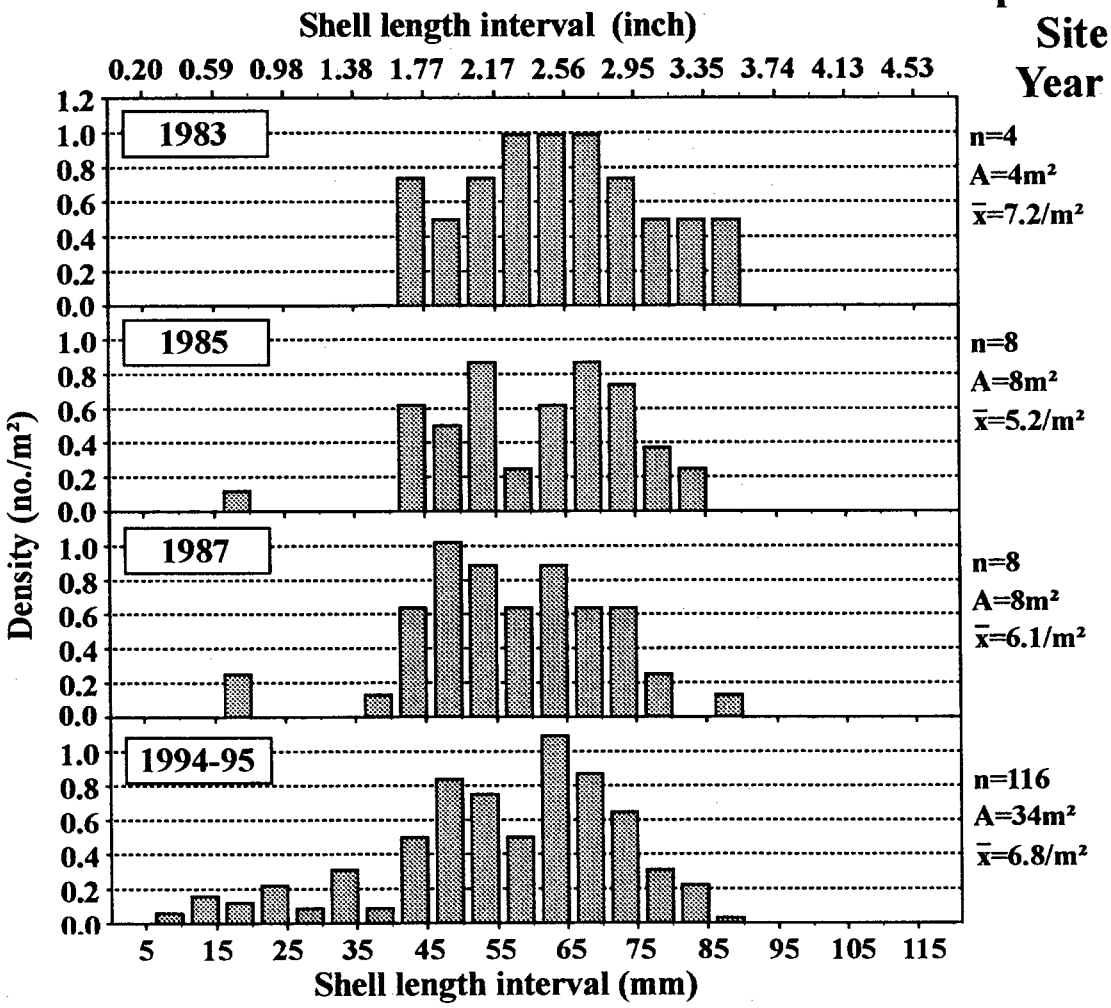


Length Interval (mm)	Density (no./m²) 1983	1985	1987	1994-95	Length Interval (inch)
5	0	0	0	0	0.20
10	0	0	0	0.06	0.39
15	0	0	0	0.16	0.59
20	0	0.12	0.25	0.12	0.79
25	0	0.00	0.00	0.22	0.98
30	0.00	0.00	0.00	0.09	1.18
35	0.00	0.00	0.00	0.31	1.38
40	0.00	0.00	0.13	0.09	1.57
45	0.74	0.62	0.64	0.50	1.77
50	0.50	0.50	1.02	0.84	1.97
55	0.74	0.87	0.89	0.75	2.17
60	0.99	0.25	0.64	0.50	2.36
65	0.99	0.62	0.89	1.09	2.56
70	0.99	0.87	0.64	0.87	2.76
75	0.74	0.74	0.64	0.65	2.95
80	0.50	0.37	0.25	0.31	3.15
85	0.50	0.25	0.00	0.22	3.35
90	0.50	0	0.13	0.03	3.54
95	0	0	0	0	3.74
100	0	0	0	0	3.94
105	0	0	0	0	4.13
110	0	0	0	0	4.33
115	0	0	0	0	4.53
120	0	0	0	0	4.72
Mean Density	**7.20**	**5.20**	**6.10**	**6.80**	

n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.

Figure C-16. Density distribution based on shell length of *Ellipsaria lineolata* (Butterfly) from Sylvan Slough site (RM 485.8) inReach 15 of the Upper Mississippi River, 1983, 1985, 1987, and 1994-95.

Species : *Ellipsaria lineolata*
Site : Sylvan Slough (RM 485.8)
Year : 1983, 1985, 1987, and 1994-95

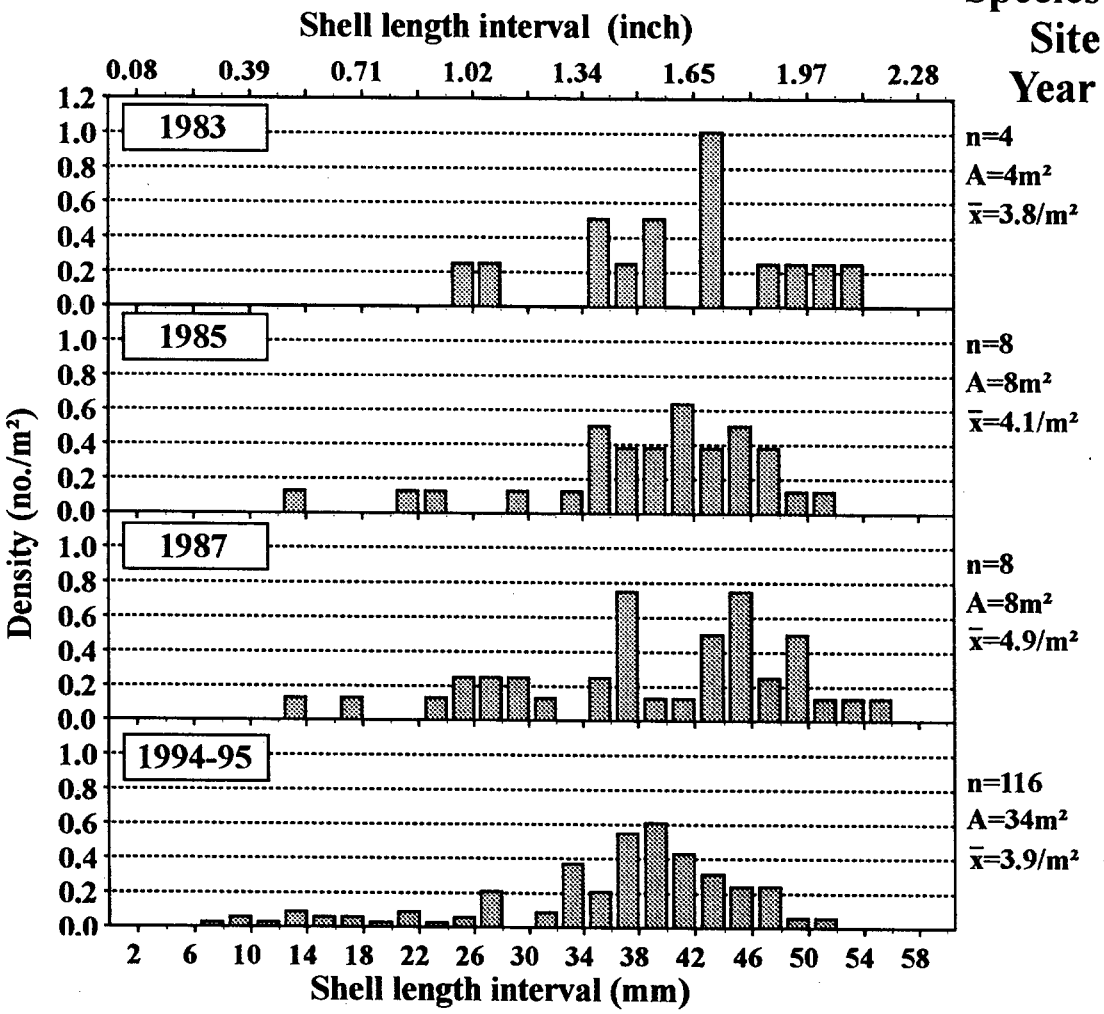


Length Interval (mm)	Density (no./m²) 1983	1985	1987	1994-95	Length Interval (inch)
5	0	0	0	0	0.20
10	0.25	0	0	0.03	0.39
15	0.00	0	0.13	0.03	0.59
20	0.25	0	0.25	0.06	0.79
25	0.00	0.37	0.38	0.06	0.98
30	0.00	0.00	0.38	0.19	1.18
35	0.75	0.25	1.13	0.10	1.38
40	0.00	0.37	0.25	0.26	1.57
45	0.25	0.37	0.63	0.19	1.77
50	0.00	0.62	0.63	0.23	1.97
55	0.75	0.50	0.38	0.10	2.17
60	0.50	0.75	0.88	0.06	2.36
65	0.25	1.50	1.38	0.00	2.56
70	0.75	1.00	0.75	0.10	2.76
75	2.74	0.50	1.00	0.00	2.95
80	0.50	0.75	1.00	0.03	3.15
85	0.75	1.12	0.38	0.03	3.35
90	0.50	0.87	0.13	0.00	3.54
95	0.00	0.37	0.25	0.03	3.74
100	0.50	0.37	0.00	0.10	3.94
105	0.00	0.37	0.38	0.03	4.13
110	0.25	0	0	0.10	4.33
115	0.25	0	0	0.03	4.53
120	0	0	0	0	4.72
Mean Density	9.20	10.10	10.30	1.78	

n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.

Figure C-17. Density distribution based on shell length of *Obliquaria reflexa* (Threehorn) from Sylvan Slough site (RM 485.8) inReach 15 of the Upper Mississippi River, 1983, 1985, 1987, and 1994-95.

Species : *Obliquaria reflexa*
Site : Sylvan Slough (RM 485.8)
Year : 1983, 1985, 1987, and 1994-95

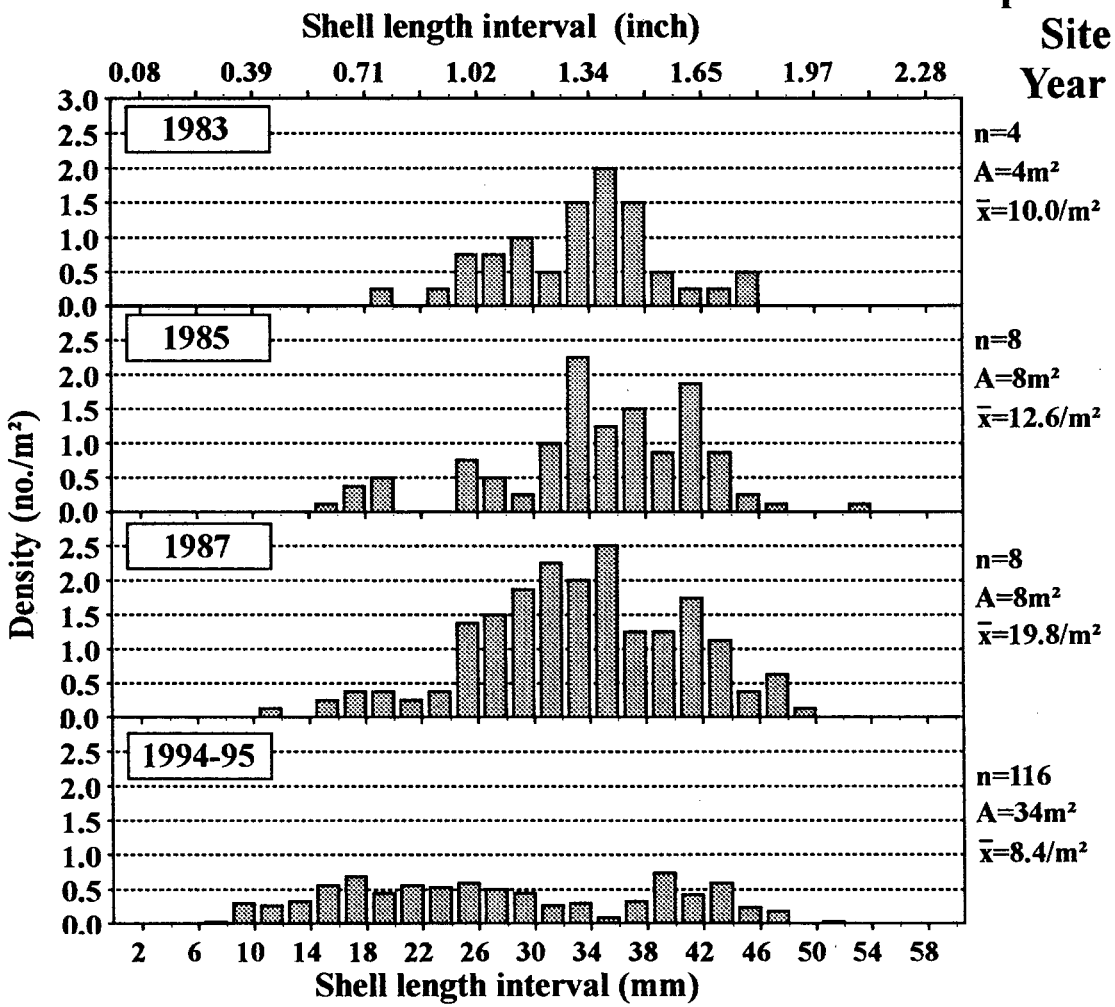


n = number of quantitative samples collected.
A = Total area (m²) of n quantitative samples.
x̄ = mean density from n quantitative samples.

Length Interval (mm)	Density (no./m²) 1983	1985	1987	1994-95	Length Interval (inch)
2	0	0	0	0	0.08
4	0	0	0	0	0.16
6	0	0	0	0	0.24
8	0	0	0	0.03	0.31
10	0	0	0	0.06	0.39
12	0	0	0	0.03	0.47
14	0	0.13	0.13	0.09	0.55
16	0	0.00	0.00	0.06	0.63
18	0	0.00	0.13	0.06	0.71
20	0	0.00	0.00	0.03	0.79
22	0	0.13	0.00	0.09	0.87
24	0	0.13	0.13	0.03	0.94
26	0.25	0.00	0.25	0.06	1.02
28	0.25	0.00	0.25	0.21	1.10
30	0.00	0.13	0.25	0.00	1.18
32	0.00	0.00	0.13	0.09	1.26
34	0.00	0.13	0.00	0.37	1.34
36	0.51	0.51	0.25	0.21	1.42
38	0.25	0.38	0.75	0.55	1.50
40	0.51	0.38	0.13	0.61	1.57
42	0.00	0.64	0.13	0.43	1.65
44	1.01	0.38	0.50	0.31	1.73
46	0.00	0.51	0.75	0.24	1.81
48	0.25	0.38	0.25	0.24	1.89
50	0.25	0.13	0.50	0.06	1.97
52	0.25	0.13	0.13	0.06	2.05
54	0.25	0	0.13	0	2.13
56	0	0	0.13	0	2.20
58	0	0	0	0	2.28
60	0	0	0	0	2.36
Mean Density	**3.80**	**4.10**	**4.90**	**3.94**	

Figure C-18. Density distribution based on shell length of *Truncilla truncata* (Deertoe) from Sylvan Slough site (RM 485.8) in Reach 15 of the Upper Mississippi River, 1983, 1985, 1987, and 1994-95.

Species : *Truncilla truncata*
Site : Sylvan Slough (RM 485.8)
Year : 1983, 1985, 1987, and 1994-95

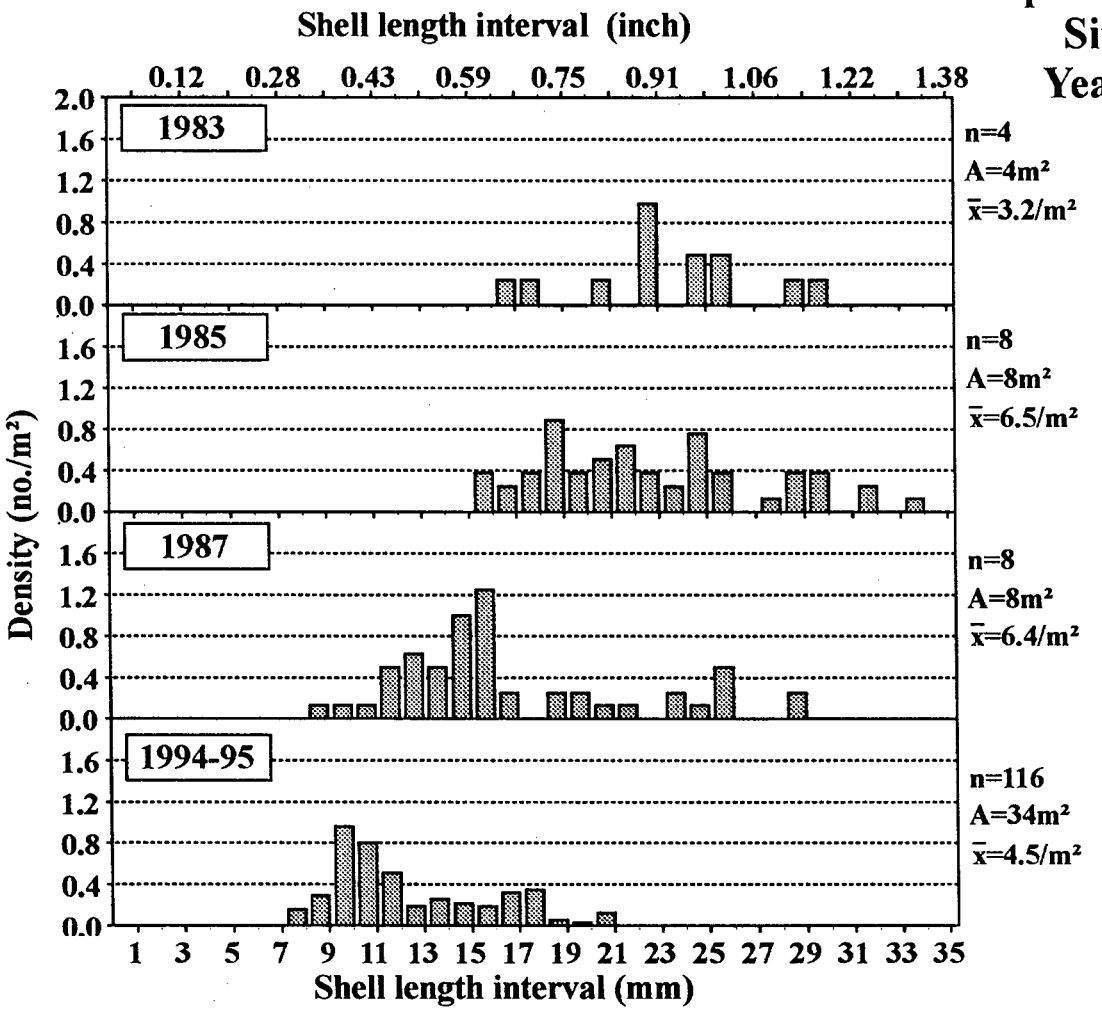


n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.

Length Interval (mm)	Density (no./m²) 1983	1985	1987	1994-95	Length Interval (inch)
2	0	0	0	0	0.08
4	0	0	0	0	0.16
6	0	0	0	0	0.24
8	0	0	0	0.03	0.31
10	0	0	0	0.30	0.39
12	0	0	0.13	0.27	0.47
14	0	0	0.00	0.33	0.55
16	0	0.12	0.25	0.56	0.63
18	0	0.37	0.38	0.68	0.71
20	0.25	0.50	0.38	0.45	0.79
22	0.00	0.00	0.25	0.56	0.87
24	0.25	0.00	0.38	0.53	0.94
26	0.75	0.75	1.38	0.59	1.02
28	0.75	0.50	1.50	0.51	1.10
30	1.00	0.25	1.88	0.45	1.18
32	0.50	1.00	2.26	0.27	1.26
34	1.50	2.25	2.01	0.30	1.34
36	2.00	1.25	2.51	0.09	1.42
38	1.50	1.50	1.25	0.33	1.50
40	0.50	0.87	1.25	0.74	1.57
42	0.25	1.87	1.75	0.42	1.65
44	0.25	0.87	1.13	0.59	1.73
46	0.50	0.25	0.38	0.24	1.81
48	0	0.12	0.63	0.18	1.89
50	0	0.00	0.13	0.00	1.97
52	0	0.00	0	0.03	2.05
54	0	0.12	0	0	2.13
56	0	0	0	0	2.20
58	0	0	0	0	2.28
60	0	0	0	0	2.36
Mean Density	**10.00**	**12.60**	**19.80**	**8.44**	

Figure C-19. Density distribution based on shell length of *Truncilla donaciformis* (Fawnsfoot) from Sylvan Slough site (RM 485.8) in Reach 15 of the Upper Mississippi River, 1983, 1985, 1987, and 1994-95.

Species : *Truncilla donaciformis*
Site : Sylvan Slough (RM 485.8)
Year : 1983, 1985, 1987, and 1994-95



n = number of quantitative samples collected.
A = Total area (m²) of n quantitative samples.
x̄ = mean density from n quantitative samples.

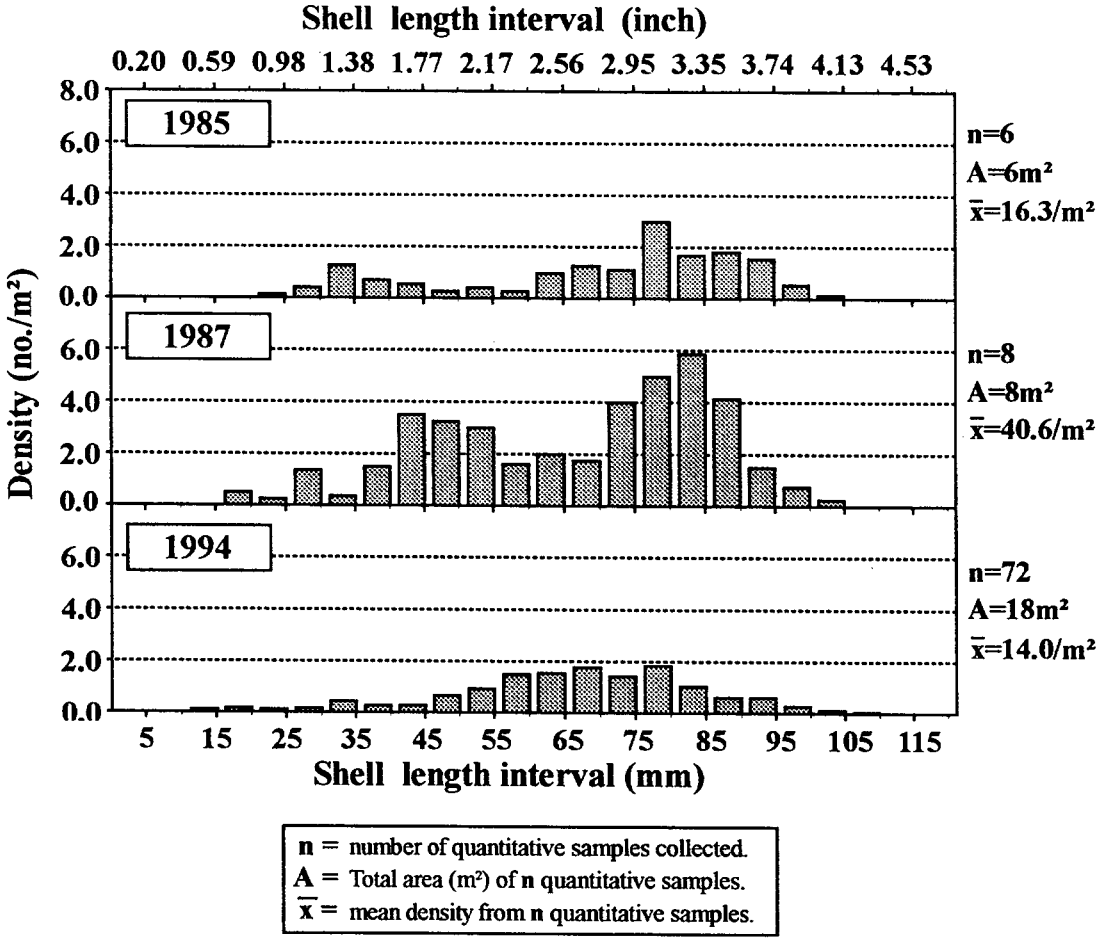
Length Interval (mm)	Density (no./m²) 1983	1985	1987	1994-95	Length Interval (inch)
1	0	0	0	0	0.04
2	0	0	0	0	0.08
3	0	0	0	0	0.12
4	0	0	0	0	0.16
5	0	0	0	0	0.20
6	0	0	0	0	0.24
7	0	0	0	0	0.28
8	0	0	0	0.16	0.31
9	0	0	0.13	0.29	0.35
10	0	0	0.13	0.96	0.39
11	0	0	0.13	0.80	0.43
12	0	0	0.50	0.51	0.47
13	0.00	0	0.63	0.19	0.51
14	0.00	0	0.50	0.26	0.55
15	0.00	0	1.00	0.22	0.59
16	0.00	0.38	1.25	0.19	0.63
17	0.25	0.25	0.25	0.32	0.67
18	0.25	0.38	0.00	0.35	0.71
19	0.00	0.89	0.25	0.06	0.75
20	0.00	0.38	0.25	0.03	0.79
21	0.25	0.51	0.13	0.13	0.83
22	0.00	0.64	0.13	0	0.87
23	0.98	0.38	0.00	0	0.91
24	0.00	0.25	0.25	0	0.94
25	0.49	0.76	0.13	0	0.98
26	0.49	0.38	0.50	0	1.02
27	0.00	0.00	0.00	0	1.06
28	0.00	0.13	0.00	0	1.10
29	0.25	0.38	0.25	0	1.14
30	0.25	0.38	0	0	1.18
31	0	0.00	0	0	1.22
32	0	0.25	0	0	1.26
33	0	0.00	0	0	1.30
34	0	0.13	0	0	1.34
35	0	0	0	0	1.38
Mean Density	3.20	6.50	6.40	4.49	

Part III.

Density distributions for unionid species at Case-IH (RM 488.5) from 1985, 1987, and 1994.

Figure C-20. Density distribution based on shell length of *Amblema plicata* (Threeridge) from Case-IH site (RM 488.5) in Pool 15 of the Upper Mississippi River, 1985, 1987, and 1994.

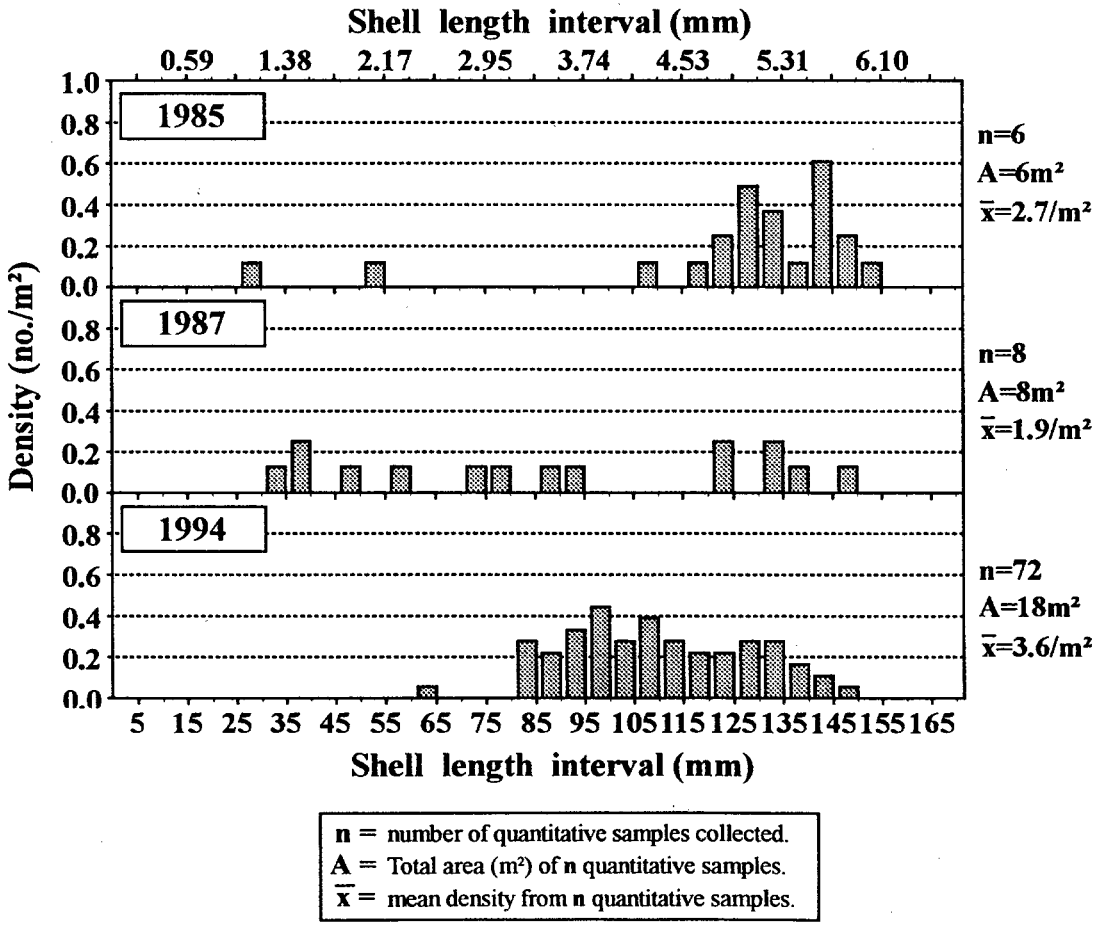
Species : *Amblema plicata*
Site : Case-IH (RM 488.5)
Year : 1985, 1987, and 1994



Length Interval (mm)	Density (no./m²) 1985	1987	1994	Length Interval (inch)
5	0	0	0	0.20
10	0	0	0	0.39
15	0	0	0.11	0.59
20	0	0.50	0.17	0.79
25	0.06	0.25	0.11	0.98
30	0.17	1.37	0.17	1.18
35	0.51	0.37	0.44	1.38
40	0.28	1.50	0.28	1.57
45	0.23	3.50	0.28	1.77
50	0.11	3.25	0.67	1.97
55	0.17	3.00	0.94	2.17
60	0.11	1.62	1.50	2.36
65	0.40	2.00	1.56	2.56
70	0.51	1.75	1.78	2.76
75	0.45	4.00	1.44	2.95
80	1.19	5.00	1.83	3.15
85	0.68	5.87	1.06	3.35
90	0.73	4.12	0.61	3.54
95	0.62	1.50	0.61	3.74
100	0.23	0.75	0.28	3.94
105	0.06	0.25	0.11	4.13
110	0	0	0.06	4.33
115	0	0	0	4.53
120	0	0	0	4.72
Mean Density	**6.50**	**40.60**	**14.00**	

Figure C-21. Density distribution based on shell length of *Megalonaias nervosa* (Washboard) from Case-IH site (RM 488.5) in Pool 15 of the Upper Mississippi River, 1985, 1987, and 1994.

Species : *Megalonaias nervosa*
Site : Case-IH (RM 488.5)
Year : 1985, 1987, and 1994

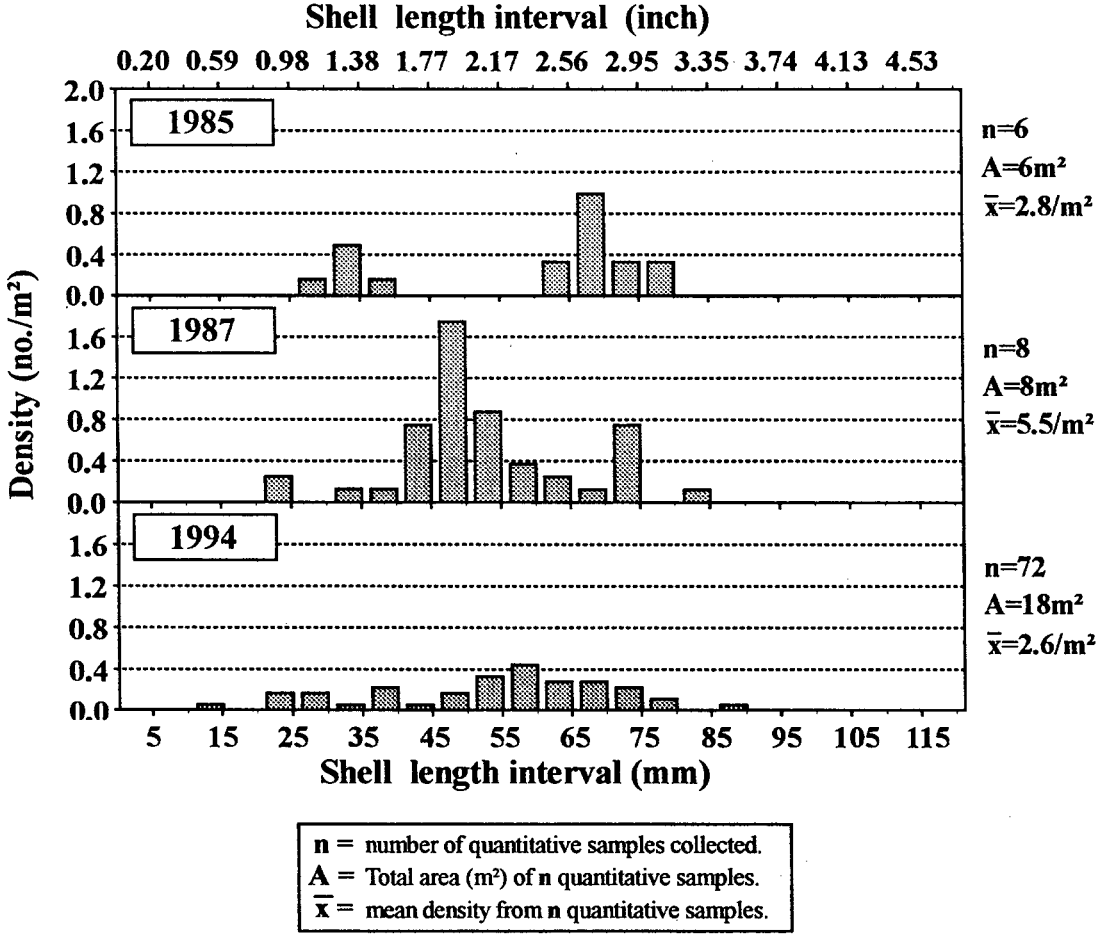


n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.

Length Interval (mm)	Density (no./m²) 1985	1987	1994	Length Interval (inch)
5	0	0	0	0.20
10	0	0	0	0.39
15	0	0	0	0.59
20	0	0	0	0.79
25	0	0	0	0.98
30	0.66	0	0	1.18
35	0.00	0.13	0	1.38
40	0.00	0.25	0	1.57
45	0.00	0.00	0	1.77
50	0.00	0.13	0	1.97
55	0.66	0.00	0	2.17
60	0.00	0.13	0	2.36
65	0.00	0.00	0.06	2.56
70	0.00	0.00	0.00	2.76
75	0.00	0.13	0.00	2.95
80	0.00	0.13	0.00	3.15
85	0.00	0.00	0.28	3.35
90	0.00	0.13	0.22	3.54
95	0.00	0.13	0.33	3.74
100	0.00	0.00	0.44	3.94
105	0.00	0.00	0.28	4.13
110	0.66	0.00	0.39	4.33
115	0.00	0.00	0.28	4.53
120	0.66	0.00	0.22	4.72
125	1.32	0.25	0.22	4.92
130	2.64	0.00	0.28	5.12
135	1.98	0.25	0.28	5.31
140	0.66	0.13	0.17	5.51
145	3.30	0.00	0.11	5.71
150	1.32	0.13	0.06	5.91
155	0.66	0	0	6.10
160	0	0	0	6.30
165	0	0	0	6.50
170	0	0	0	6.69
Mean Density	**14.50**	**1.90**	**3.61**	

Figure C-22. Density distribution based on shell length of *Quadrula quadrula* (Mapleleaf) from Case-IH site (RM 488.5) in Pool 15 of the Upper Mississippi River, 1985, 1987, and 1994.

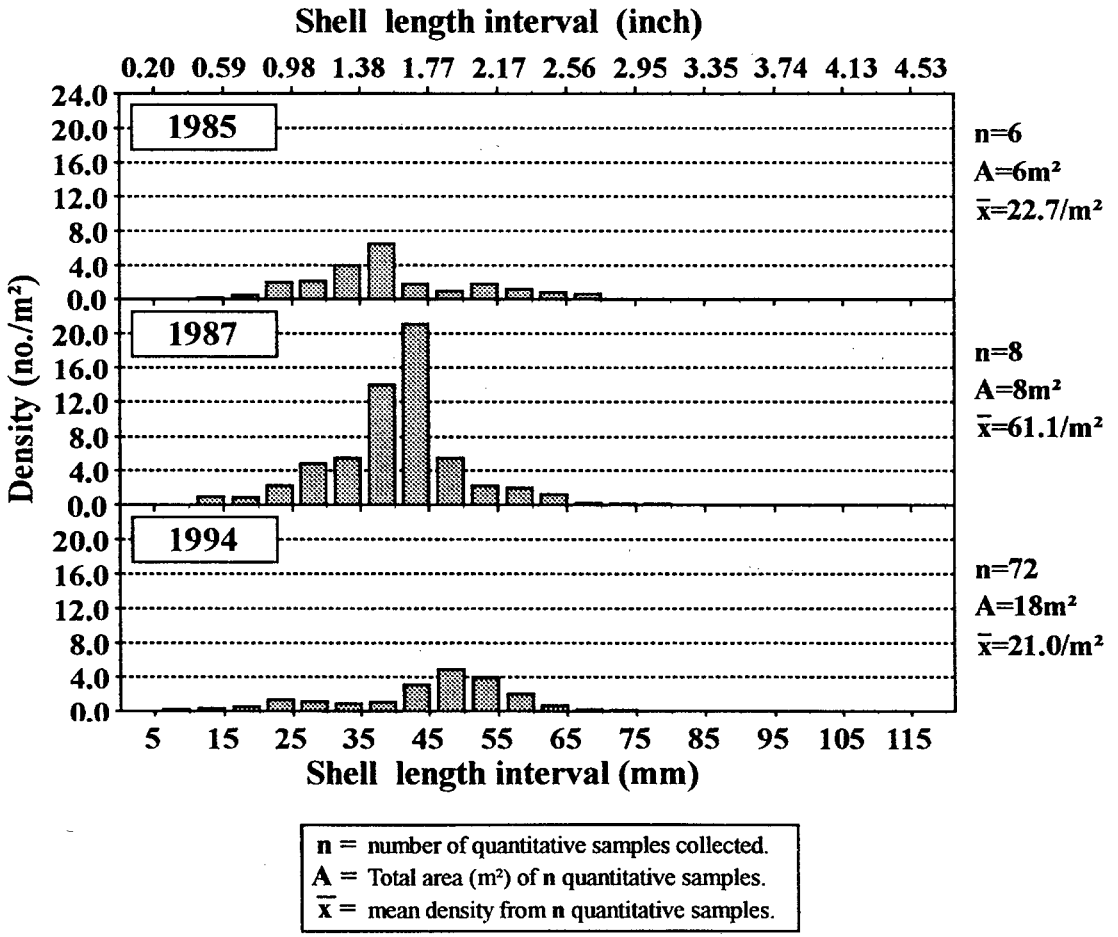
Species : *Quadrula quadrula*
Site : Case-IH (RM 488.5)
Year : 1985, 1987, and 1994



Length Interval (mm)	Density (no./m²) 1985	1987	1994	Length Interval (inch)
5	0	0	0	0.20
10	0	0	0	0.39
15	0	0	0.06	0.59
20	0	0	0.00	0.79
25	0	0.25	0.17	0.98
30	0.08	0.00	0.17	1.18
35	0.23	0.13	0.06	1.38
40	0.08	0.13	0.22	1.57
45	0.00	0.75	0.06	1.77
50	0.00	1.75	0.17	1.97
55	0.00	0.875	0.33	2.17
60	0.00	0.375	0.44	2.36
65	0.15	0.25	0.28	2.56
70	0.46	0.125	0.28	2.76
75	0.15	0.75	0.22	2.95
80	0.15	0	0.11	3.15
85	0	0.125	0.00	3.35
90	0	0	0.06	3.54
95	0	0	0	3.74
100	0	0	0	3.94
105	0	0	0	4.13
110	0	0	0	4.33
115	0	0	0	4.53
120	0	0	0	4.72
Mean Density	**1.30**	**5.50**	**2.61**	

Figure C-23. Density distribution based on shell length of *Quadrula pustulosa* (Pimpleback) from Case-IH site (RM 488.5) in Pool 15 of the Upper Mississippi River, 1985, 1987, and 1994.

Species : *Quadrula pustulosa*
Site : Case-IH (RM 488.5)
Year : 1985, 1987, and 1994

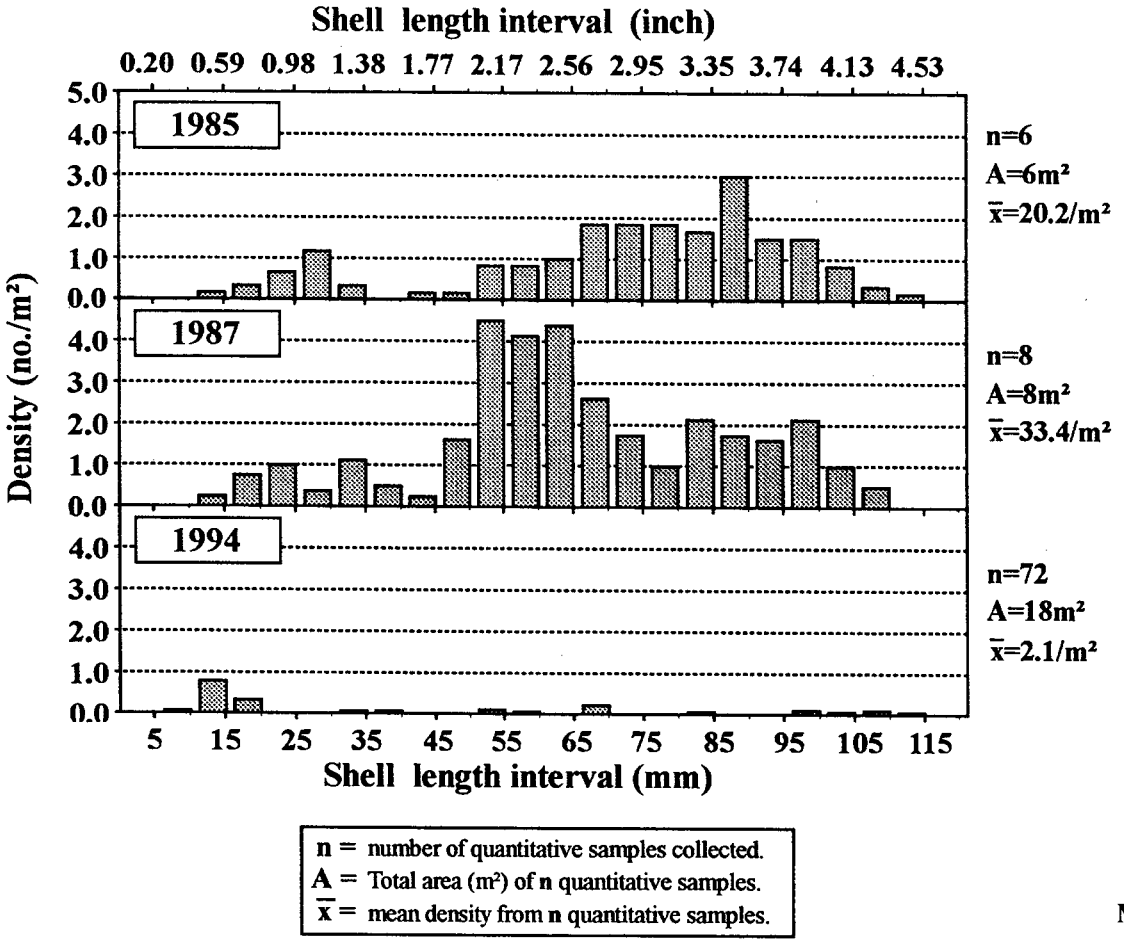


n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.

Length Interval (mm)	Density (no./m²) 1985	1987	1994	Length Interval (inch)
5	0	0	0	0.20
10	0	0	0.22	0.39
15	0.21	1.00	0.33	0.59
20	0.63	0.87	0.61	0.79
25	2.51	2.25	1.39	0.98
30	2.71	4.87	1.17	1.18
35	5.01	5.50	0.89	1.38
40	8.14	13.99	1.11	1.57
45	2.30	21.12	3.17	1.77
50	1.25	5.50	4.94	1.97
55	2.30	2.25	3.94	2.17
60	1.46	2.00	2.11	2.36
65	1.04	1.25	0.72	2.56
70	0.84	0.25	0.22	2.76
75	0	0.12	0.17	2.95
80	0	0.12	0	3.15
85	0	0.00	0	3.35
90	0	0	0	3.54
95	0	0	0	3.74
100	0	0	0	3.94
105	0	0	0	4.13
110	0	0	0	4.33
115	0	0	0	4.53
120	0	0	0	4.72
Mean Density	**28.40**	**61.10**	**21.00**	

Figure C-24. Density distribution based on shell length of *Leptodea fragilis* (Fragile papershell) from Case-IH site (RM 488.5) in Pool 15 of the Upper Mississippi River, 1985, 1987, and 1994.

Species : *Leptodea fragilis*
Site : Case-IH (RM 488.5)
Year : 1985, 1987, and 1994

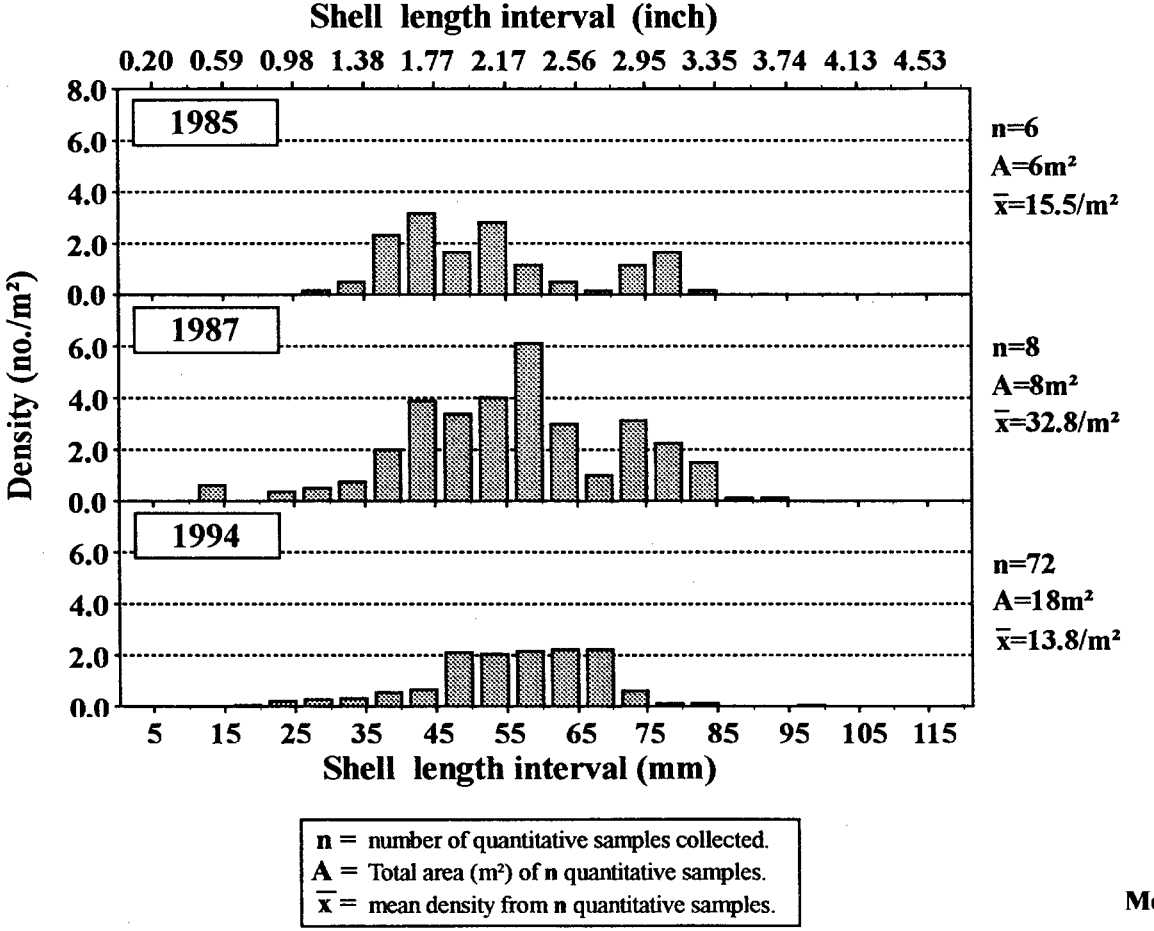


n = number of quantitative samples collected.
A = Total area (m²) of n quantitative samples.
$\bar{x}$ = mean density from n quantitative samples.

Length Interval (mm)	Density (no./m²) 1985	1987	1994	Length Interval (inch)
5	0	0	0	0.20
10	0	0	0	0.39
15	0	0.63	0	0.59
20	0	0.00	0.06	0.79
25	0	0.38	0.22	0.98
30	0.07	0.50	0.28	1.18
35	0.20	0.75	0.33	1.38
40	0.92	2.00	0.56	1.57
45	1.25	3.88	0.67	1.77
50	0.66	3.38	2.11	1.97
55	1.12	4.01	2.06	2.17
60	0.46	6.13	2.17	2.36
65	0.20	3.00	2.22	2.56
70	0.07	1.00	2.22	2.76
75	0.46	3.13	0.61	2.95
80	0.66	2.25	0.11	3.15
85	0.07	1.50	0.11	3.35
90	0	0.13	0.00	3.54
95	0	0.13	0.00	3.74
100	0	0	0.06	3.94
105	0	0	0	4.13
110	0	0	0	4.33
115	0	0	0	4.53
120	0	0	0	4.72
Mean Density	**6.10**	**32.80**	**13.78**	

Figure C-25. Density distribution based on shell length of *Ellipsaria lineolata* (Butterfly) from Case-IH site (RM 488.5) in Pool 15 of the Upper Mississippi River, 1985, 1987, and 1994.

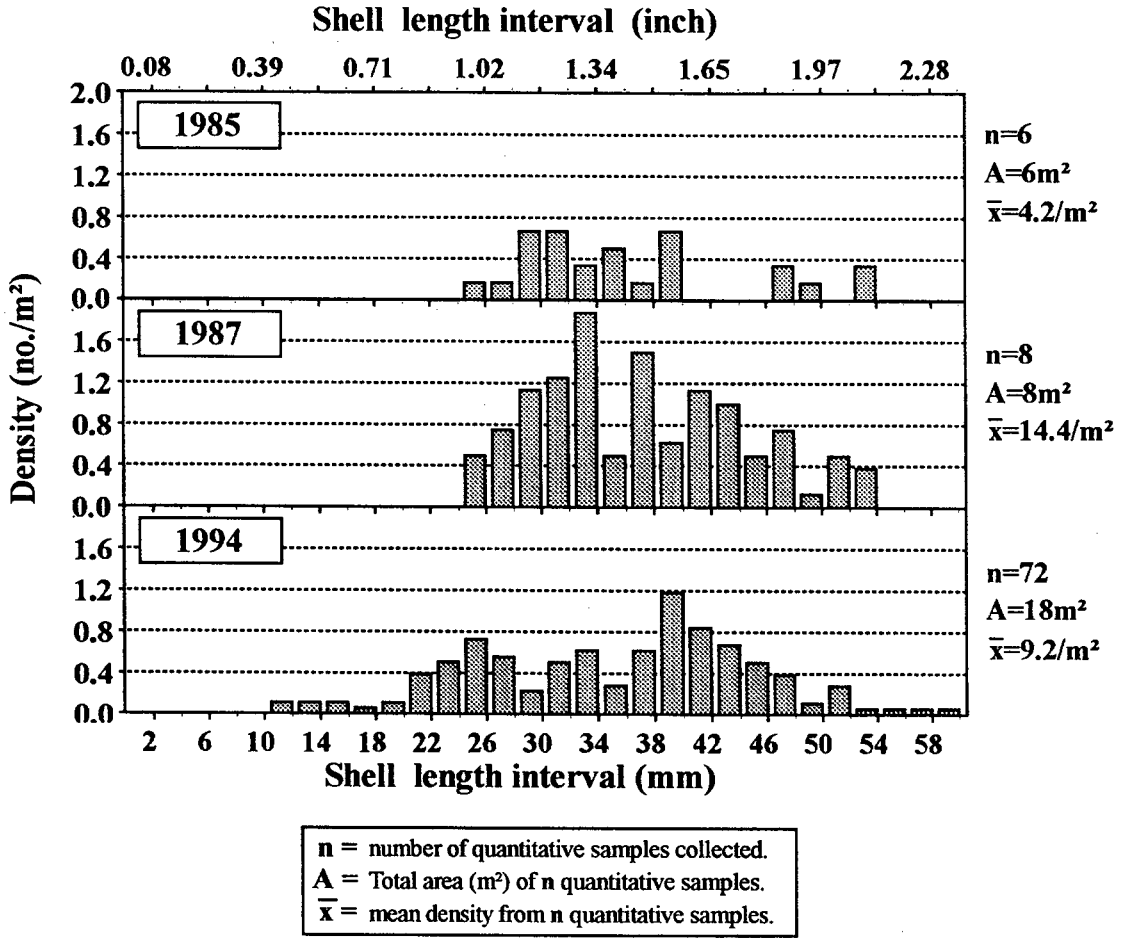
Species : *Ellipsaria lineolata*
Site : Case-IH (RM 488.5)
Year : 1985, 1987, and 1994



Length Interval (mm)	Density (no./m²) 1985	1987	1994	Length Interval (inch)
5	0	0	0	0.20
10	0	0	0.06	0.39
15	0.17	0.25	0.78	0.59
20	0.33	0.75	0.33	0.79
25	0.67	1.00	0.00	0.98
30	1.17	0.38	0.00	1.18
35	0.33	1.13	0.06	1.38
40	0.00	0.50	0.06	1.57
45	0.17	0.25	0.00	1.77
50	0.17	1.63	0.00	1.97
55	0.83	4.50	0.11	2.17
60	0.83	4.13	0.06	2.36
65	1.00	4.38	0.00	2.56
70	1.84	2.63	0.22	2.76
75	1.84	1.75	0.00	2.95
80	1.84	1.00	0.00	3.15
85	1.67	2.13	0.06	3.35
90	3.00	1.75	0.00	3.54
95	1.50	1.63	0.00	3.74
100	1.50	2.13	0.11	3.94
105	0.83	1.00	0.06	4.13
110	0.33	0.50	0.11	4.33
115	0.17	0	0.06	4.53
120	0	0	0	4.72
Mean Density	**20.20**	**33.40**	**2.06**	

Figure C-26. Density distribution based on shell length of *Obliquaria reflexa* (Threehorn) from Case-IH site (RM 488.5) in Pool 15 of the Upper Mississippi River, 1985, 1987, and 1994.

Species : *Obliquaria reflexa*
Site : Case-IH (RM 488.5)
Year : 1985, 1987, and 1994

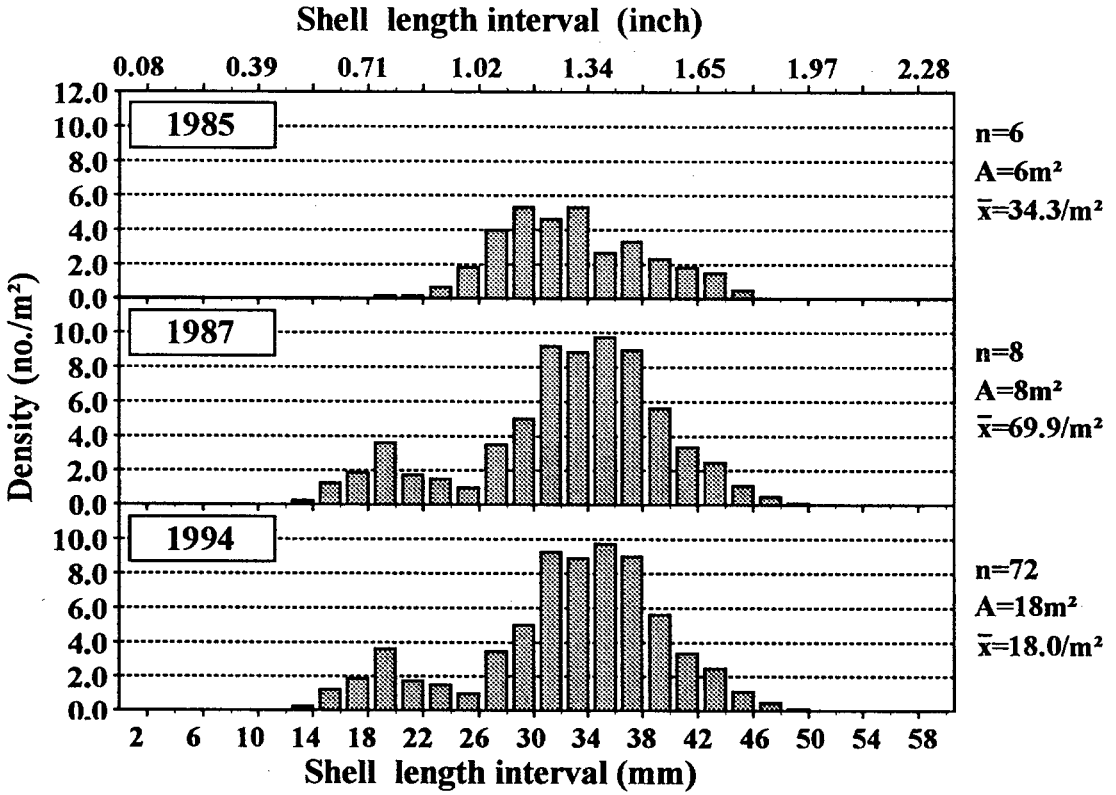


n = number of quantitative samples collected.
A = Total area (m²) of n quantitative samples.
x̄ = mean density from n quantitative samples.

Length Interval (mm)	Density (no./m²) 1985	1987	1994	Length Interval (inch)
2	0	0	0	0.08
4	0	0	0	0.16
6	0	0	0	0.24
8	0	0	0	0.31
10	0	0	0	0.39
12	0	0	0.11	0.47
14	0	0	0.11	0.55
16	0	0	0.11	0.63
18	0	0	0.06	0.71
20	0	0	0.11	0.79
22	0	0	0.39	0.87
24	0	0	0.51	0.94
26	0.17	0.50	0.73	1.02
28	0.17	0.75	0.56	1.10
30	0.67	1.13	0.23	1.18
32	0.67	1.25	0.51	1.26
34	0.34	1.88	0.62	1.34
36	0.50	0.50	0.28	1.42
38	0.17	1.50	0.62	1.50
40	0.67	0.63	1.18	1.57
42	0.00	1.13	0.84	1.65
44	0.00	1.00	0.68	1.73
46	0.00	0.50	0.51	1.81
48	0.34	0.75	0.39	1.89
50	0.17	0.13	0.11	1.97
52	0.00	0.50	0.28	2.05
54	0.34	0.38	0.06	2.13
56	0	0	0.06	2.20
58	0	0	0.06	2.28
60	0	0	0.06	2.36
Mean Density	**4.20**	**14.40**	**9.17**	

Figure C-27. Density distribution based on shell length of *Truncilla truncata* (Deertoe) from Case-IH site (RM 488.5) in Pool 15 of the Upper Mississippi River, 1985, 1987, and 1994.

Species : *Truncilla truncata*
Site : Case-IH (RM 488.5)
Year : 1985, 1987, and 1994

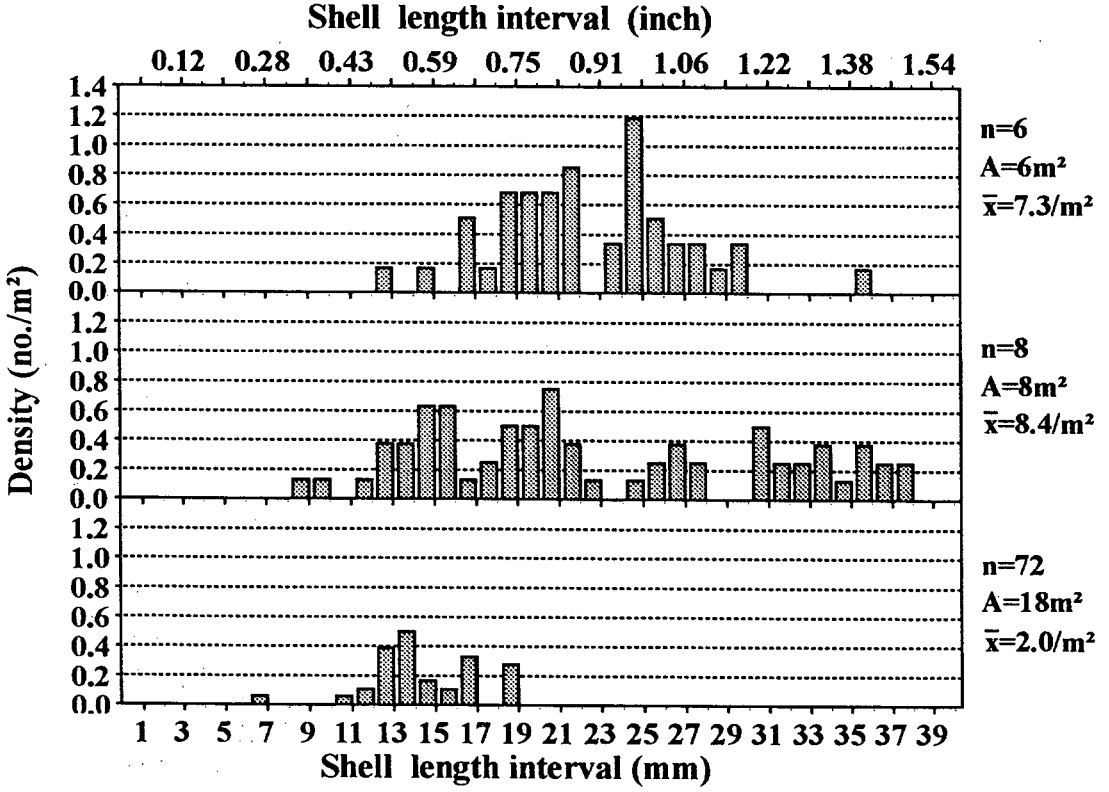


n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.

Length Interval (mm)	Density (no./m²) 1985	1987	1994	Length Interval (inch)
2	0	0	0	0.08
4	0	0	0.06	0.16
6	0	0	0.06	0.24
8	0	0	0.00	0.31
10	0	0	0.17	0.39
12	0	0	0.78	0.47
14	0	0.25	1.06	0.55
16	0	1.25	1.89	0.63
18	0	1.88	0.94	0.71
20	0.10	3.63	0.72	0.79
22	0.10	1.75	0.33	0.87
24	0.38	1.50	0.22	0.94
26	1.06	1.00	0.39	1.02
28	2.31	3.50	0.50	1.10
30	3.08	5.00	0.56	1.18
32	2.69	9.25	0.72	1.26
34	3.08	8.88	0.67	1.34
36	1.54	9.75	0.33	1.42
38	1.92	9.00	1.28	1.50
40	1.35	5.63	1.56	1.57
42	1.06	3.38	2.22	1.65
44	0.87	2.50	1.11	1.73
46	0.29	1.13	0.89	1.81
48	0	0.50	0.44	1.89
50	0	0.13	0.28	1.97
52	0	0	0.22	2.05
54	0	0	0.11	2.13
56	0	0	0.00	2.20
58	0	0	0.06	2.28
60	0	0	0.33	2.36
Mean Density	**19.80**	**69.90**	**17.89**	

Figure C-28. Density distribution based on shell length of *Truncilla donaciformis* (Fawnsfoot) from Case-IH site (RM 488.5) in Pool 15 of the Upper Mississippi River, 1985, 1987, and 1994.

Species : *Truncilla donaciformis*
Site : Case-IH (RM 488.5)
Year : 1985, 1987, and 1994



n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.

Length Interval (mm)	Density (no./m²) 1985	1987	1994	Length Interval (inch)
1	0	0	0	0.04
2	0	0	0	0.08
3	0	0	0	0.12
4	0	0	0	0.16
5	0	0	0	0.20
6	0	0	0	0.24
7	0	0	0.06	0.28
8	0	0	0.00	0.31
9	0	0.13	0.00	0.35
10	0	0.13	0.00	0.39
11	0	0.00	0.06	0.43
12	0	0.13	0.11	0.47
13	0.17	0.38	0.39	0.51
14	0.00	0.38	0.50	0.55
15	0.17	0.63	0.17	0.59
16	0.00	0.63	0.11	0.63
17	0.51	0.13	0.33	0.67
18	0.17	0.25	0.00	0.71
19	0.68	0.50	0.28	0.75
20	0.68	0.50	0	0.79
21	0.68	0.75	0	0.83
22	0.85	0.38	0	0.87
23	0.00	0.13	0	0.91
24	0.34	0.00	0	0.94
25	1.19	0.13	0	0.98
26	0.51	0.25	0	1.02
27	0.34	0.38	0	1.06
28	0.34	0.25	0	1.10
29	0.17	0.00	0	1.14
30	0.34	0.00	0	1.18
31	0.00	0.50	0	1.22
32	0.00	0.25	0	1.26
33	0.00	0.25	0	1.30
34	0.00	0.38	0	1.34
35	0.00	0.13	0	1.38
36	0.17	0.38	0	1.42
37	0	0.25	0	1.46
38	0	0.25	0	1.50
39	0	0	0	1.54
40	0	0	0	1.57
Mean Density	7.30	8.40	2.00	

Appendix D

Density distributions based on shell height

Reach 15 of the Upper Mississippi River

Appendix D

Density distributions based on shell height

Reach 15 of the Upper Mississippi River

Appendix C

Density distributions based on shell length

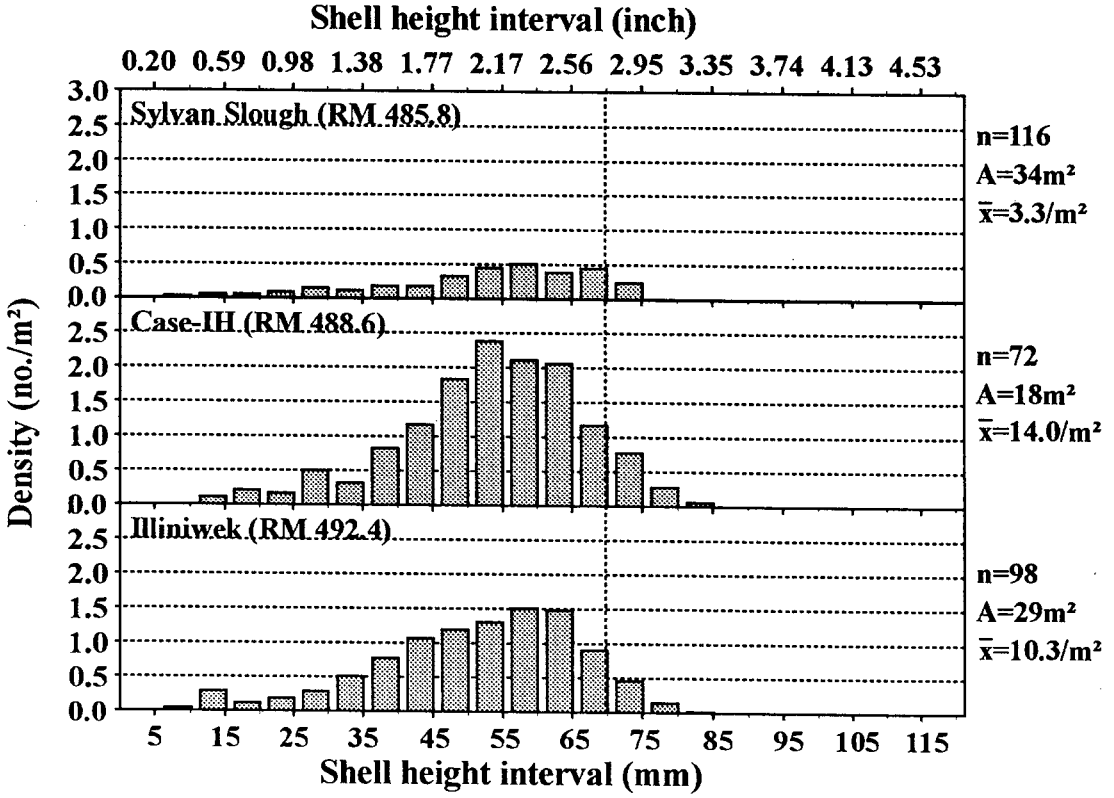
Reach 15 of the Upper Mississippi River

Part I.

Density distributions for commercial mussel species from Sylvan Slough (RM 485.8), Case-IH (RM 488.6), and Illiniwek (RM 492.4), 1994-95.

Figure D-1. Density distribution based on shell height of *Amblema plicata* (Threeridge) from three sites in Reach 15 of the Upper Mississippi River, 1994-95.

Species : *Amblema plicata*
Site : Reach 15 (UMR)
Year : 1994-95

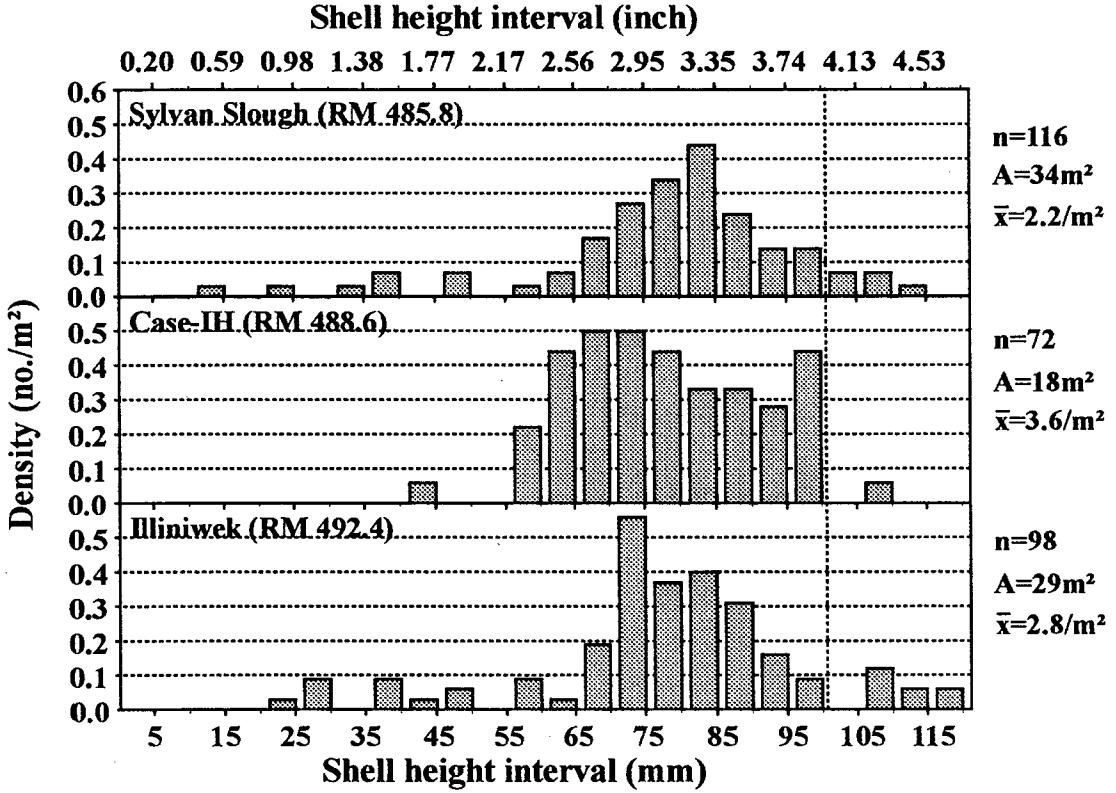


Height Interval (mm)	Density (no./m²)			Height Interval (inch)
	Sylvan	Case-IH	Illiniwek	
5	0	0	0	0.20
10	0.03	0	0.05	0.39
15	0.06	0.11	0.29	0.59
20	0.06	0.22	0.12	0.79
25	0.09	0.17	0.19	0.98
30	0.15	0.50	0.29	1.18
35	0.12	0.33	0.51	1.38
40	0.18	0.83	0.78	1.57
45	0.18	1.17	1.07	1.77
50	0.33	1.83	1.19	1.97
55	0.45	2.39	1.31	2.17
60	0.51	2.11	1.51	2.36
65	0.39	2.06	1.48	2.56
70	0.45	1.17	0.90	2.76
75	0.24	0.78	0.46	2.95
80	0	0.28	0.15	3.15
85	0	0.06	0.02	3.35
90	0	0	0	3.54
95	0	0	0	3.74
100	0	0	0	3.94
105	0	0	0	4.13
110	0	0	0	4.33
115	0	0	0	4.53
120	0	0	0	4.72
Mean Density	**3.24**	**14.00**	**10.34**	

n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.
⋮ = minimum commercial shell height = 69.9 mm (2.75 inch)

Figure D-2. Density distribution based on shell height of *Megalonaias nervosa* (Washboard) from three sites in Reach 15 of the Upper Mississippi River, 1994-95.

Species : *Megalonaias nervosa*
Site : Reach 15 (UMR)
Year : 1994-95

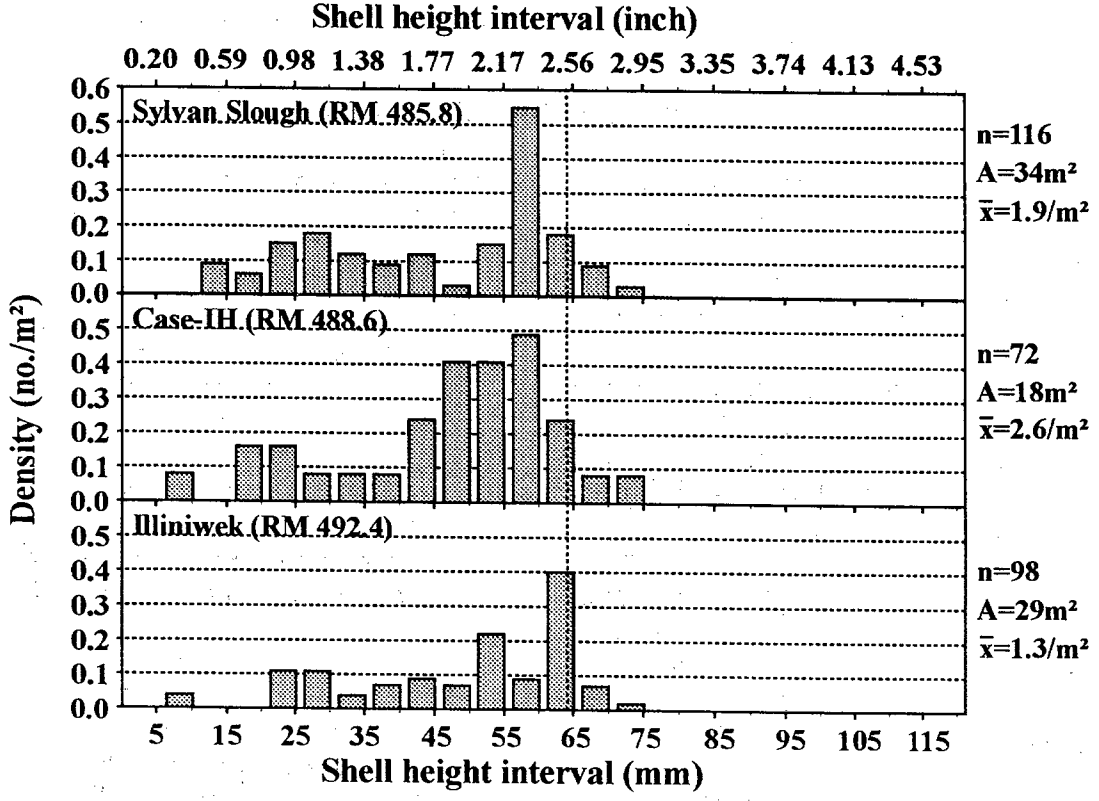


Height Interval (mm)	Density (no./m²) Sylvan	Case-IH	Illiniwek	Height Interval (inch)
5	0	0	0	0.20
10	0	0	0	0.39
15	0.03	0	0	0.59
20	0.00	0	0	0.79
25	0.03	0	0.03	0.98
30	0.00	0	0.09	1.18
35	0.03	0	0.00	1.38
40	0.07	0	0.09	1.57
45	0.00	0.06	0.03	1.77
50	0.07	0.00	0.06	1.97
55	0.00	0.00	0.00	2.17
60	0.03	0.22	0.09	2.36
65	0.07	0.44	0.03	2.56
70	0.17	0.50	0.19	2.76
75	0.27	0.50	0.56	2.95
80	0.34	0.44	0.37	3.15
85	0.44	0.33	0.40	3.35
90	0.24	0.33	0.31	3.54
95	0.14	0.28	0.16	3.74
100	0.14	0.44	0.09	3.94
105	0.07	0.00	0.00	4.13
110	0.07	0.06	0.12	4.33
115	0.03	0	0.06	4.53
120	0	0	0.06	4.72
Mean Density	2.24	3.61	2.77	

n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.
⋮ = minimum commercial shell height = 101.6 mm (4.0 inch)

Figure D-3. Density distribution based on shell height of *Quadrula quadrula* (Mapleleaf) from three sites in Reach 15 of the Upper Mississippi River, 1994-95.

Species : *Quadrula quadrula*
Site : Reach 15 (UMR)
Year : 1994-95

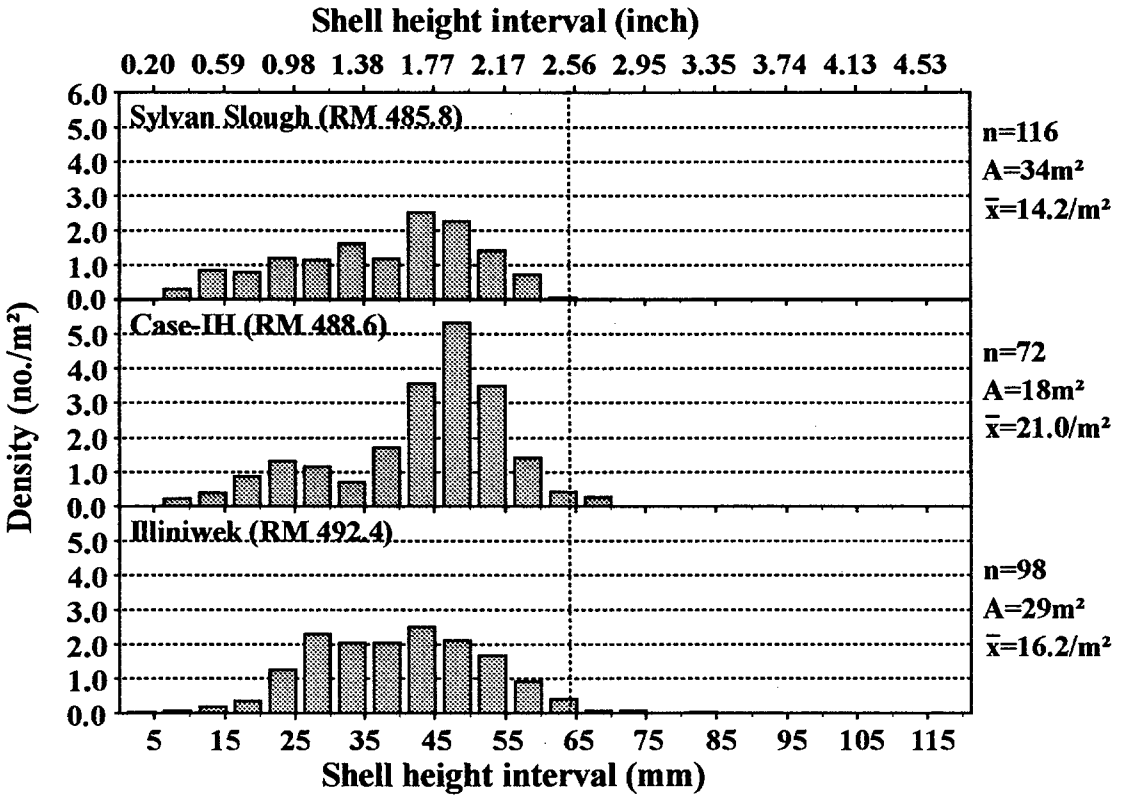


Height Interval (mm)	Density (no./m²) Sylvan	Case-IH	Illiniwek	Height Interval (inch)
5	0	0	0	0.20
10	0	0.08	0.04	0.39
15	0.09	0.00	0.00	0.59
20	0.06	0.16	0.00	0.79
25	0.15	0.16	0.11	0.98
30	0.18	0.08	0.11	1.18
35	0.12	0.08	0.04	1.38
40	0.09	0.08	0.07	1.57
45	0.12	0.24	0.09	1.77
50	0.03	0.41	0.07	1.97
55	0.15	0.41	0.22	2.17
60	0.55	0.49	0.09	2.36
65	0.18	0.24	0.40	2.56
70	0.09	0.08	0.07	2.76
75	0.03	0.08	0.02	2.95
80	0	0	0	3.15
85	0	0	0	3.35
90	0	0	0	3.54
95	0	0	0	3.74
100	0	0	0	3.94
105	0	0	0	4.13
110	0	0	0	4.33
115	0	0	0	4.53
120	0	0	0	4.72
Mean Density	**1.85**	**2.61**	**1.33**	

n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.
⋮ = minimum commercial shell height = 63.7mm (2.5 inch)

Figure D-4. Density distribution based on shell height of *Quadrula pustulosa* (Pimpleback) from three sites in Reach 15 of the Upper Mississippi River, 1994-95.

Species : *Quadrula pustulosa*
Site : Reach 15 (UMR)
Year : 1994-95



Height Interval (mm)	Density (no./m²) Sylvan	Case-IH	Illiniwek	Height Interval (inch)
5	0	0	0.04	0.20
10	0.30	0.22	0.07	0.39
15	0.85	0.39	0.19	0.59
20	0.79	0.89	0.37	0.79
25	1.21	1.33	1.27	0.98
30	1.15	1.17	2.31	1.18
35	1.63	0.72	2.05	1.38
40	1.18	1.72	2.05	1.57
45	2.54	3.56	2.50	1.77
50	2.27	5.33	2.12	1.97
55	1.42	3.50	1.68	2.17
60	0.73	1.44	0.93	2.36
65	0.06	0.44	0.41	2.56
70	0	0.28	0.07	2.76
75	0	0	0.07	2.95
80	0	0	0.00	3.15
85	0	0	0.04	3.35
90	0	0	0	3.54
95	0	0	0	3.74
100	0	0	0	3.94
105	0	0	0	4.13
110	0	0	0	4.33
115	0	0	0	4.53
120	0	0	0	4.72
Mean Density	14.12	21.00	16.17	

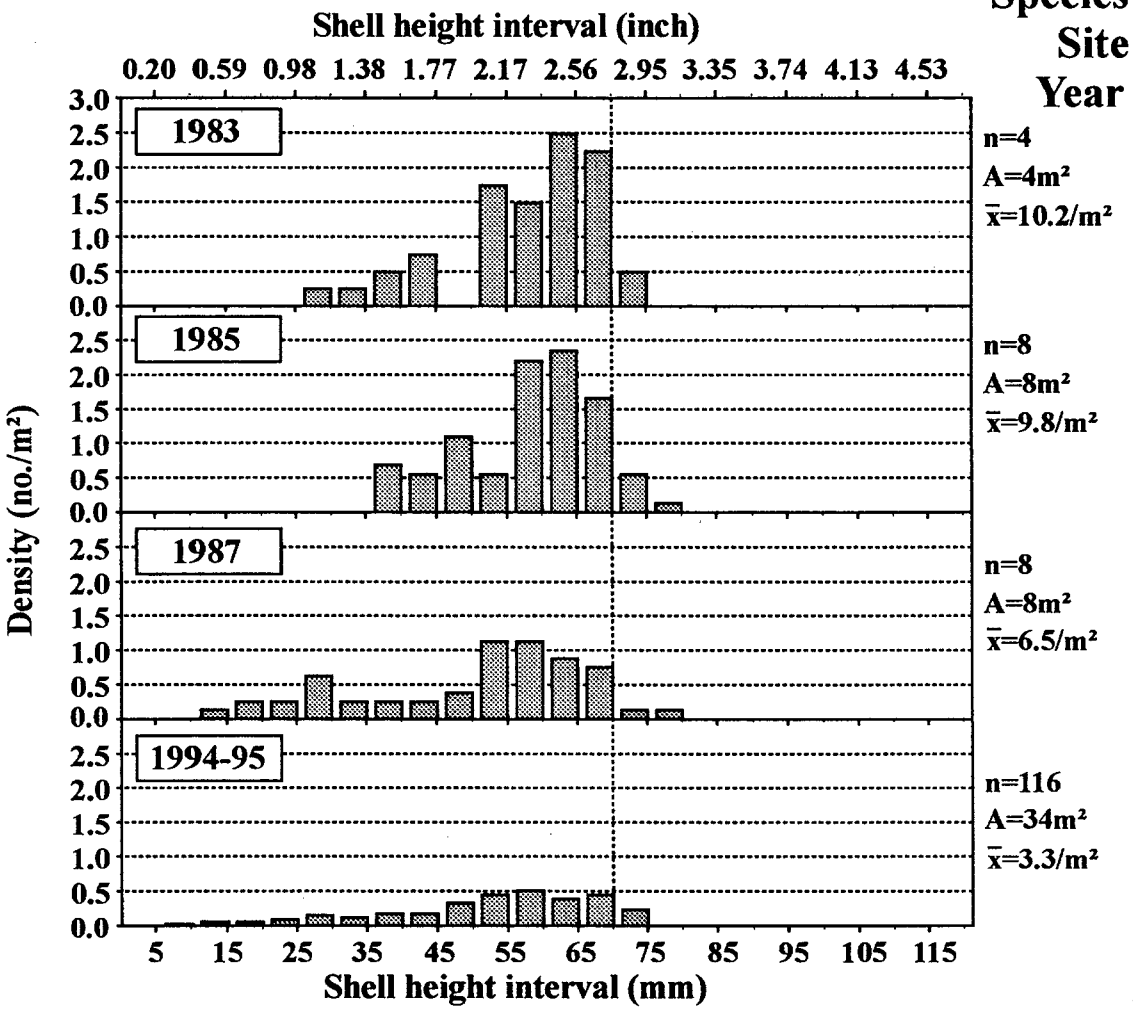
n = number of quantitative samples collected.
A = Total area (m²) of n quantitative samples.
x̄ = mean density from n quantitative samples.
⋮ = minimum commercial shell height = 63.7mm (2.5 inch)

Part II.

Density distributions for commercial mussel species at Sylvan Slough (RM 485.8) from 1983, 1985, 1987, and 1994-95.

Figure D-5. Density distribution based on shell hight of *Amblema plicata* (Threeridge) from Sylvan Slough site (RM 485.8) in Reach 15 of the Upper Mississippi River, 1983, 1985, 1987, and 1994-95.

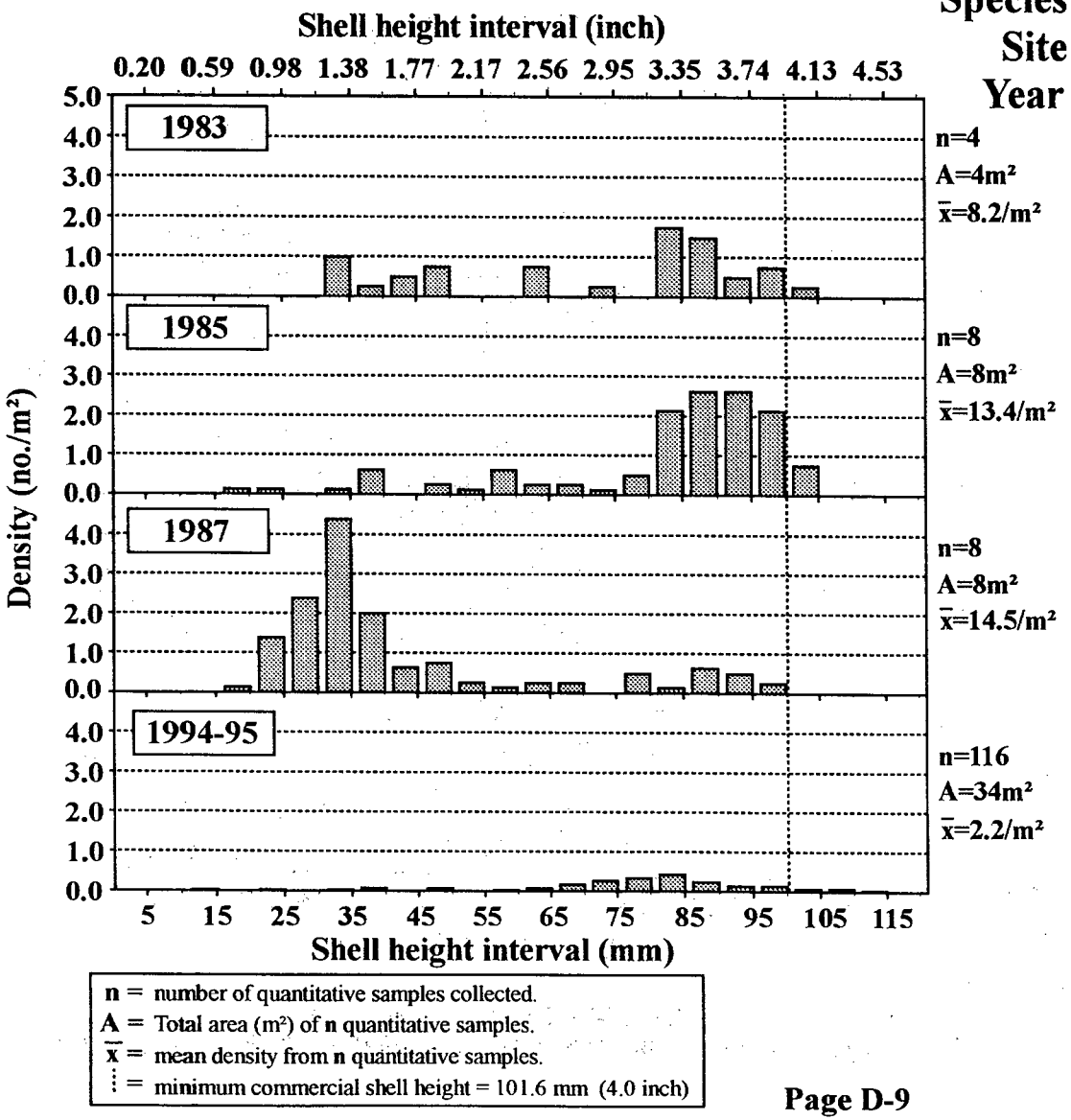
Species : *Amblema plicata*
Site : Sylvan Slough (RM 485.8)
Year : 1983, 1985, 1987, and 1994-95



Height Interval (mm)	Density (no./m²) 1983	1985	1987	1994-95	Height Interval (inch)
5	0	0	0	0	0.20
10	0	0	0	0.03	0.39
15	0	0	0.13	0.06	0.59
20	0	0	0.25	0.06	0.79
25	0	0	0.25	0.09	0.98
30	0.25	0	0.63	0.15	1.18
35	0.25	0	0.25	0.12	1.38
40	0.50	0.69	0.25	0.18	1.57
45	0.75	0.55	0.25	0.18	1.77
50	0.00	1.10	0.38	0.33	1.97
55	1.74	0.55	1.13	0.45	2.17
60	1.49	2.21	1.13	0.51	2.36
65	2.49	2.35	0.88	0.39	2.56
70	2.24	1.66	0.75	0.45	2.76
75	0.50	0.55	0.13	0.24	2.95
80	0	0.14	0.13	0	3.15
85	0	0	0	0	3.35
90	0	0	0	0	3.54
95	0	0	0	0	3.74
100	0	0	0	0	3.94
105	0	0	0	0	4.13
110	0	0	0	0	4.33
115	0	0	0	0	4.53
120	0	0	0	0	4.72
Mean Density	10.20	9.80	6.50	3.24	

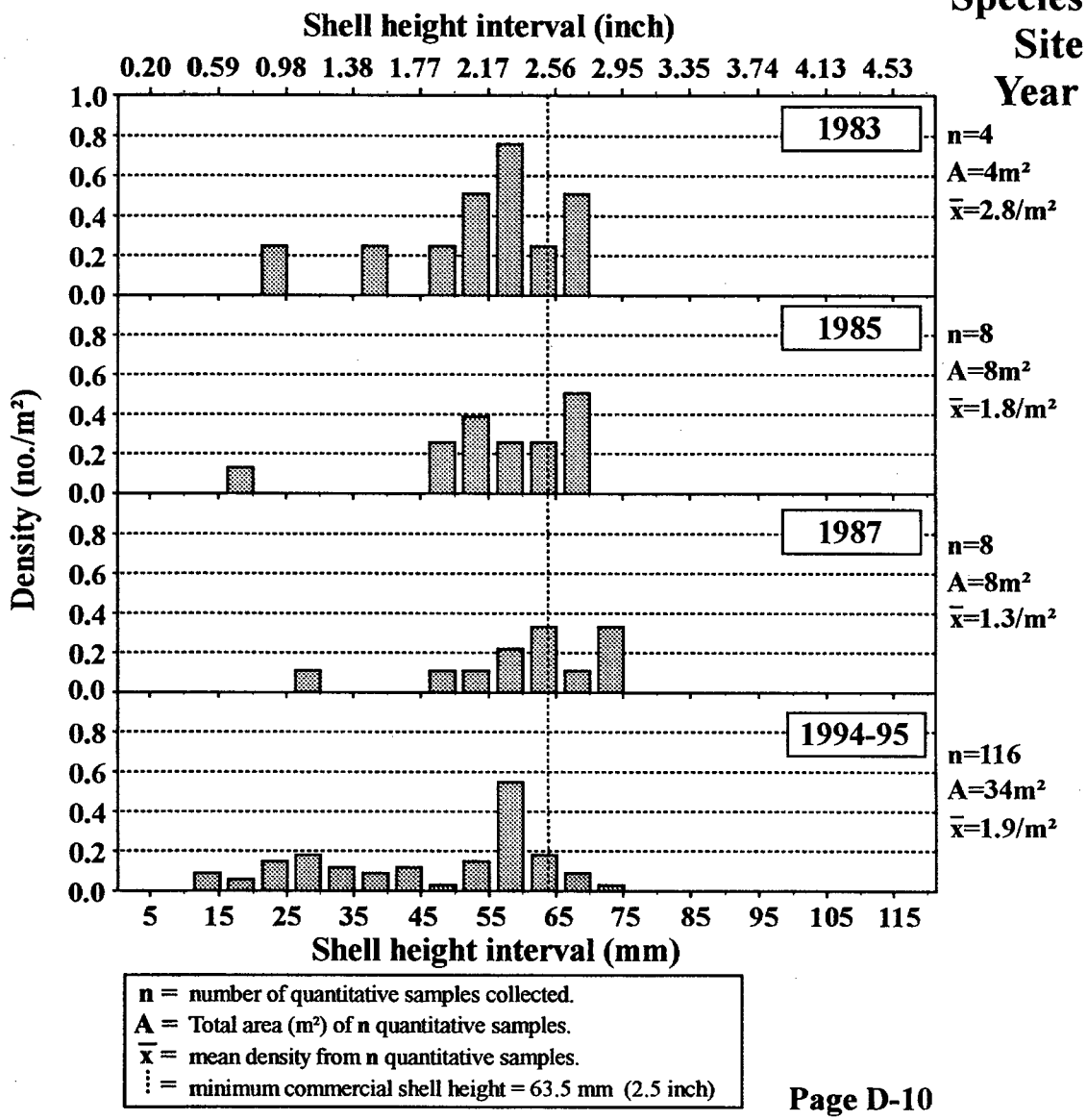
n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.
⋮ = minimum commercial shell height = 69.9 mm (2.75 inch)

Figure D-6. Density distribution based on shell height of *Megalonaias nervosa* (Washboard) from Sylvan Slough site (RM 485.8) in Reach 15 of the Upper Mississippi River, 1983, 1985, 1987, and 1994-95.



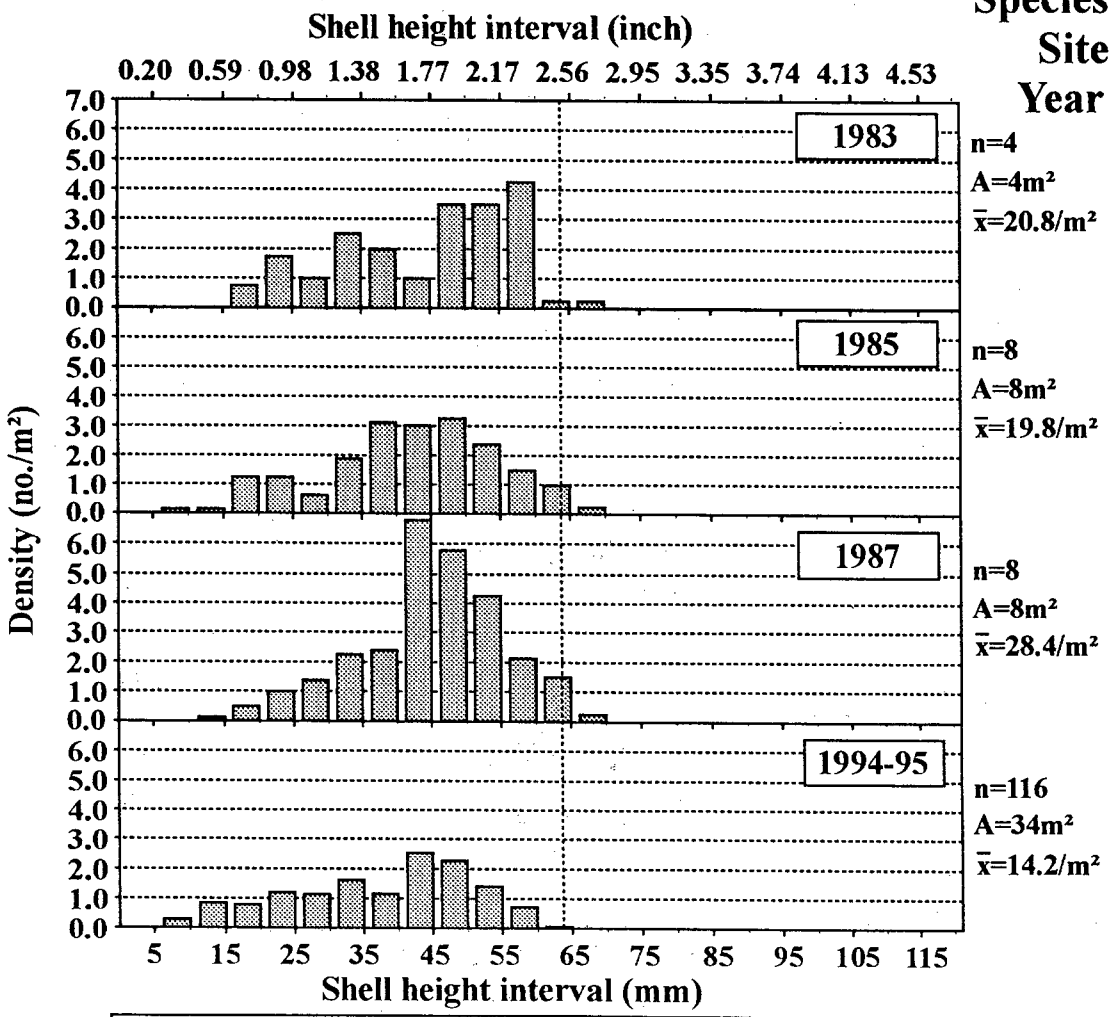
Height Interval (mm)	Density (no./m²) 1983	1985	1987	1994-95	Height Interval (inch)
5	0	0	0	0	0.20
10	0	0.00	0	0	0.39
15	0	0.00	0	0.03	0.59
20	0	0.13	0.13	0.00	0.79
25	0	0.13	1.38	0.03	0.98
30	0	0.00	2.38	0.00	1.18
35	0.99	0.13	4.38	0.03	1.38
40	0.25	0.63	2.00	0.07	1.57
45	0.50	0.00	0.63	0.00	1.77
50	0.75	0.25	0.75	0.07	1.97
55	0.00	0.13	0.25	0.00	2.17
60	0.00	0.63	0.13	0.03	2.36
65	0.75	0.25	0.25	0.07	2.56
70	0.00	0.25	0.25	0.17	2.76
75	0.25	0.13	0.00	0.27	2.95
80	0.00	0.50	0.50	0.34	3.15
85	1.74	2.13	0.13	0.44	3.35
90	1.49	2.63	0.63	0.24	3.54
95	0.50	2.63	0.50	0.14	3.74
100	0.75	2.13	0.25	0.14	3.94
105	0.25	0.75	0.00	0.07	4.13
110	0	0	0	0.07	4.33
115	0	0	0	0.03	4.53
120	0	0	0	0	4.72
Mean Density	8.20	13.40	14.50	2.24	

Figure D-7. Density distribution based on shell height of *Quadrula quadrula* (Mapleleaf) from Sylvan Slough site (RM 485.8) in Reachl 15 of the Upper Mississippi River, 1983, 1985, 1987, and 1994-95.



Height Interval (mm)	Density (no./m²) 1983	1985	1987	1994-95	Height Interval (inch)
5	0	0	0	0	0.20
10	0	0	0	0	0.39
15	0	0	0	0.09	0.59
20	0	0.13	0	0.06	0.79
25	0.25	0.00	0	0.15	0.98
30	0.00	0.00	0.11	0.18	1.18
35	0.00	0.00	0.00	0.12	1.38
40	0.25	0.00	0.00	0.09	1.57
45	0.00	0.00	0.00	0.12	1.77
50	0.25	0.26	0.11	0.03	1.97
55	0.51	0.39	0.11	0.15	2.17
60	0.76	0.26	0.22	0.55	2.36
65	0.25	0.26	0.33	0.18	2.56
70	0.51	0.51	0.11	0.09	2.76
75	0	0	0.33	0.03	2.95
80	0	0	0	0	3.15
85	0	0	0	0	3.35
90	0	0	0	0	3.54
95	0	0	0	0	3.74
100	0	0	0	0	3.94
105	0	0	0	0	4.13
110	0	0	0	0	4.33
115	0	0	0	0	4.53
120	0	0	0	0	4.72
Mean Density	2.80	1.80	1.30	1.85	

Figure D-8. Density distribution based on shell height of *Quadrula pustulosa* (Pimpleback) from Sylvan Slough site (RM 485.8) in Reach 15 of the Upper Mississippi River, 1983, 1985, 1987, and 1994-95.



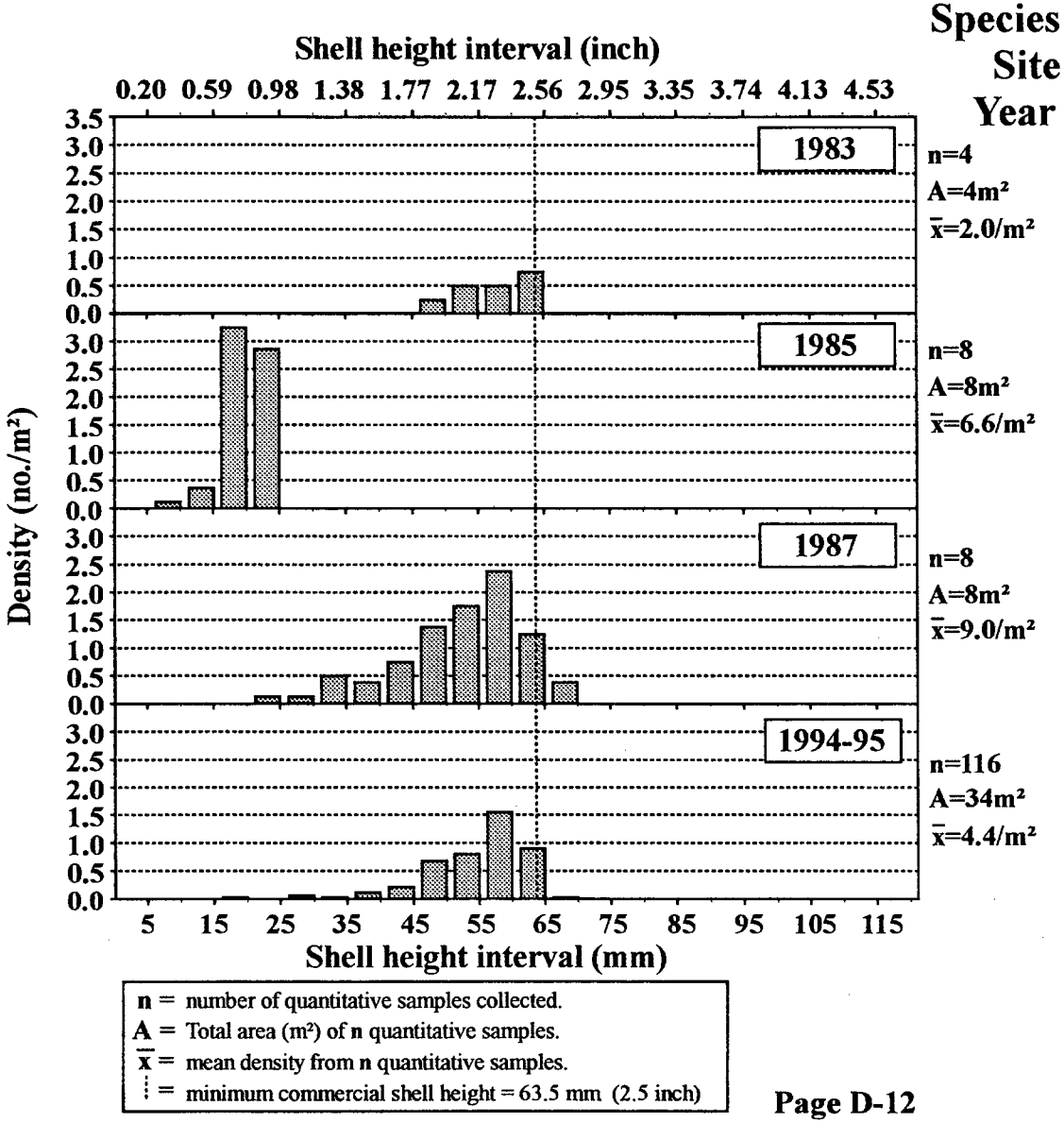
Species : *Quadrula pustulosa*
Site : Sylvan Slough (RM 485.8)
Year : 1983, 1985, 1987, and 1994-95

1983: n=4, A=4m², $\bar{x}$=20.8/m²
1985: n=8, A=8m², $\bar{x}$=19.8/m²
1987: n=8, A=8m², $\bar{x}$=28.4/m²
1994-95: n=116, A=34m², $\bar{x}$=14.2/m²

Height Interval (mm)	Density (no./m²) 1983	1985	1987	1994-95	Height Interval (inch)
5	0	0	0	0	0.20
10	0	0.13	0	0.30	0.39
15	0	0.13	0.13	0.85	0.59
20	0.75	1.25	0.50	0.79	0.79
25	1.75	1.25	1.01	1.21	0.98
30	1.00	0.63	1.38	1.15	1.18
35	2.51	1.88	2.26	1.63	1.38
40	2.00	3.13	2.39	1.18	1.57
45	1.00	3.01	6.79	2.54	1.77
50	3.51	3.26	5.78	2.27	1.97
55	3.51	2.38	4.27	1.42	2.17
60	4.26	1.50	2.14	0.73	2.36
65	0.25	1.00	1.51	0.06	2.56
70	0.25	0.25	0.25	0	2.76
75	0	0	0	0	2.95
80	0	0	0	0	3.15
85	0	0	0	0	3.35
90	0	0	0	0	3.54
95	0	0	0	0	3.74
100	0	0	0	0	3.94
105	0	0	0	0	4.13
110	0	0	0	0	4.33
115	0	0	0	0	4.53
120	0	0	0	0	4.72
Mean Density	20.80	19.80	28.40	14.12	

n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.
⋮ = minimum commercial shell height = 63.5 mm (2.5 inch)

Figure D-9. Density distribution based on shell height of *Quadrula metanevra* (Monkeyface) from Sylvan Slough site (RM 485.8) in Reach 15 of the Upper Mississippi River, 1983, 1985, 1987, and 1994-95.



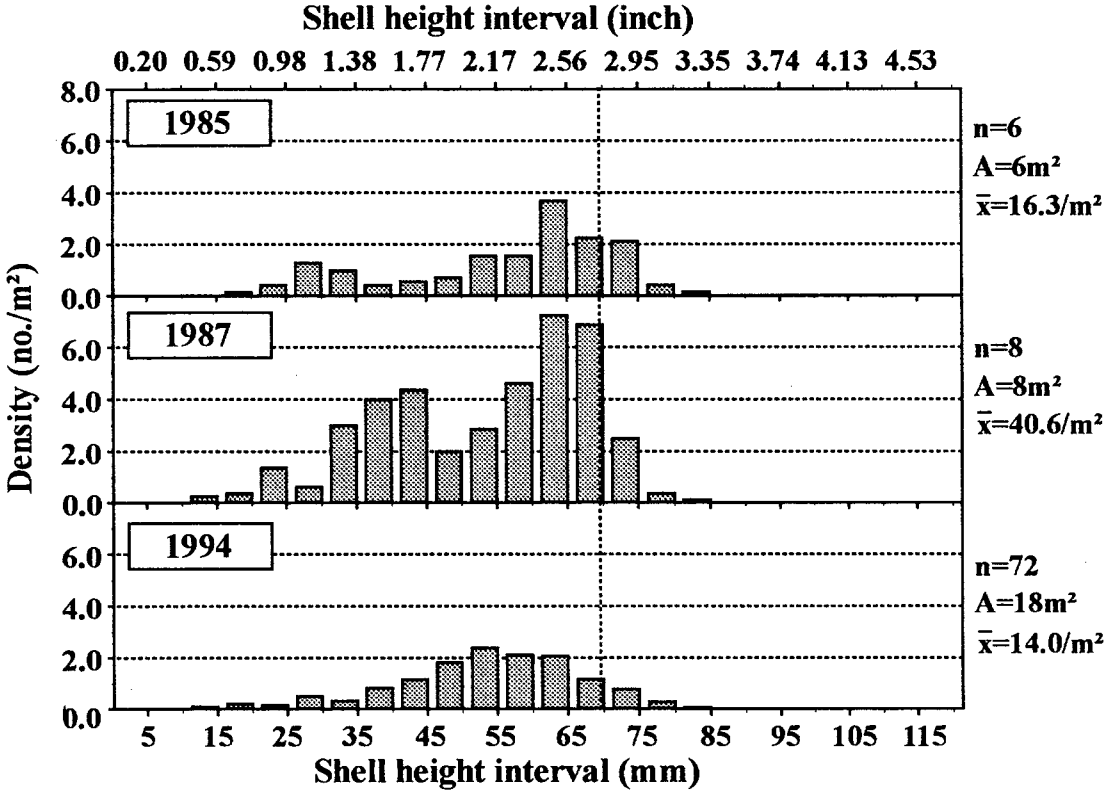
Height Interval (mm)	Density (no./m²) 1983	1985	1987	1994-95	Height Interval (inch)
5	0	0	0	0	0.20
10	0	0.12	0	0	0.39
15	0	0.37	0	0	0.59
20	0	3.24	0	0.03	0.79
25	0	2.86	0.13	0.00	0.98
30	0	0	0.13	0.06	1.18
35	0	0	0.50	0.03	1.38
40	0	0	0.38	0.12	1.57
45	0	0	0.75	0.22	1.77
50	0.25	0	1.38	0.68	1.97
55	0.50	0	1.75	0.80	2.17
60	0.50	0	2.38	1.55	2.36
65	0.75	0	1.25	0.90	2.56
70	0	0	0.38	0.03	2.76
75	0	0	0	0	2.95
80	0	0	0	0	3.15
85	0	0	0	0	3.35
90	0	0	0	0	3.54
95	0	0	0	0	3.74
100	0	0	0	0	3.94
105	0	0	0	0	4.13
110	0	0	0	0	4.33
115	0	0	0	0	4.53
120	0	0	0	0	4.72
Mean Density	2.00	6.60	9.00	4.42	

Part III.

Density distributions for commercial mussel species at Case-IH (RM 488.5) from 1985, 1987, and 1994.

Figure D-10. Density distribution based on shell height of *Amblema plicata* (Threeridge) from Case-IH site (RM 488.5) in Reach 15 of the Upper Mississippi River, 1985, 1987, and 1994.

Species : *Amblema plicata*
Site : Case-IH (RM 488.5)
Year : 1985, 1987, and 1994

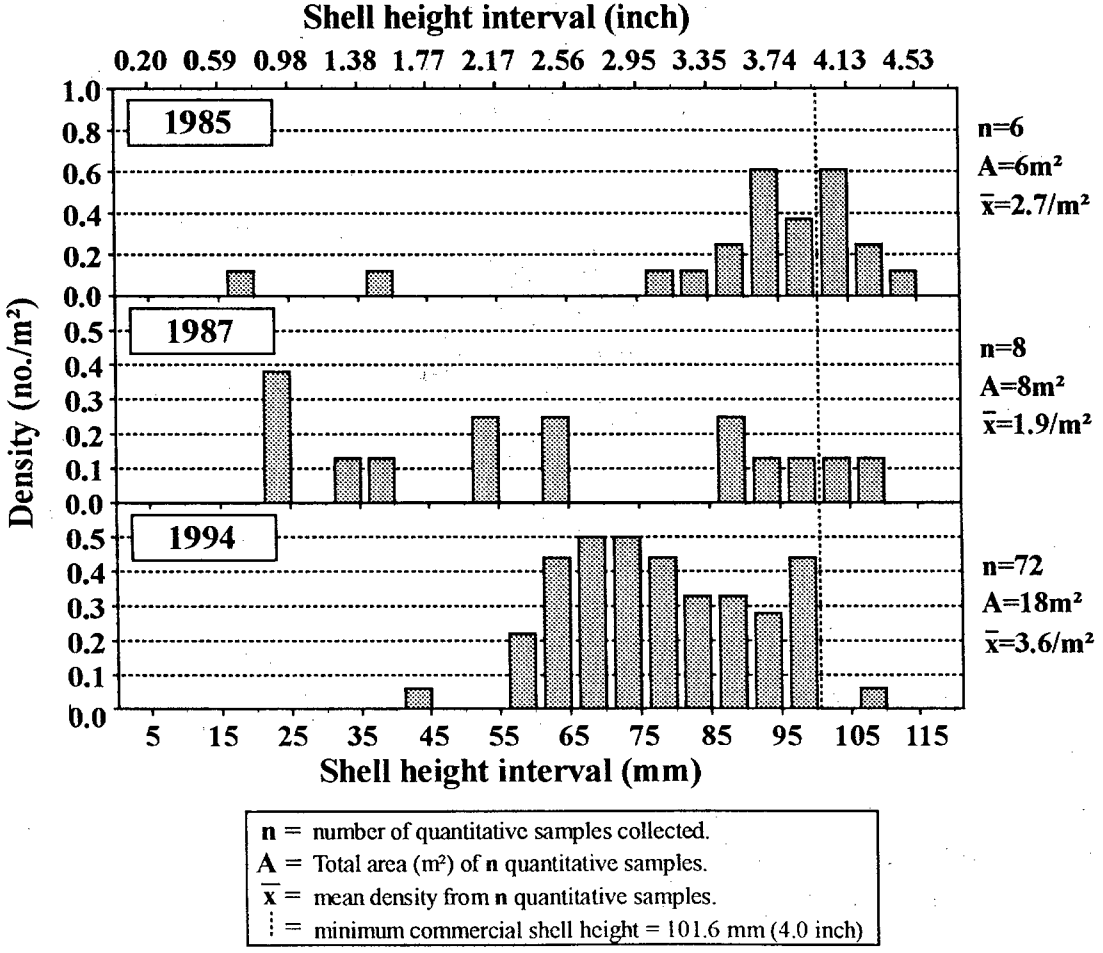


n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.
⋮ = minimum commercial shell length = 69.9 mm (2.75 inch)

Height Interval (mm)	Density (no./m²) 1985	1987	1994	Height Interval (inch)
5	0	0	0	0.20
10	0	0	0	0.39
15	0	0.25	0.11	0.59
20	0.14	0.37	0.22	0.79
25	0.43	1.37	0.17	0.98
30	1.28	0.62	0.50	1.18
35	0.99	3.00	0.33	1.38
40	0.43	4.00	0.83	1.57
45	0.57	4.37	1.17	1.77
50	0.71	2.00	1.83	1.97
55	1.56	2.87	2.39	2.17
60	1.56	4.62	2.11	2.36
65	3.69	7.25	2.06	2.56
70	2.27	6.87	1.17	2.76
75	2.13	2.50	0.78	2.95
80	0.43	0.37	0.28	3.15
85	0.14	0.12	0.06	3.35
90	0	0	0	3.54
95	0	0	0	3.74
100	0	0	0	3.94
105	0	0	0	4.13
110	0	0	0	4.33
115	0	0	0	4.53
120	0	0	0	4.72
Mean Density	**16.30**	**40.60**	**14.00**	

Figure D-11. Density distribution based on shell height of *Megalonaias nervosa* (Washboard) from Case-IH site (RM 488.5) in Reach 15 of the Upper Mississippi River, 1985, 1987, and 1994.

Species : *Megalonaias nervosa*
Site : Case-IH (RM 488.5)
Year : 1985, 1987, and 1994

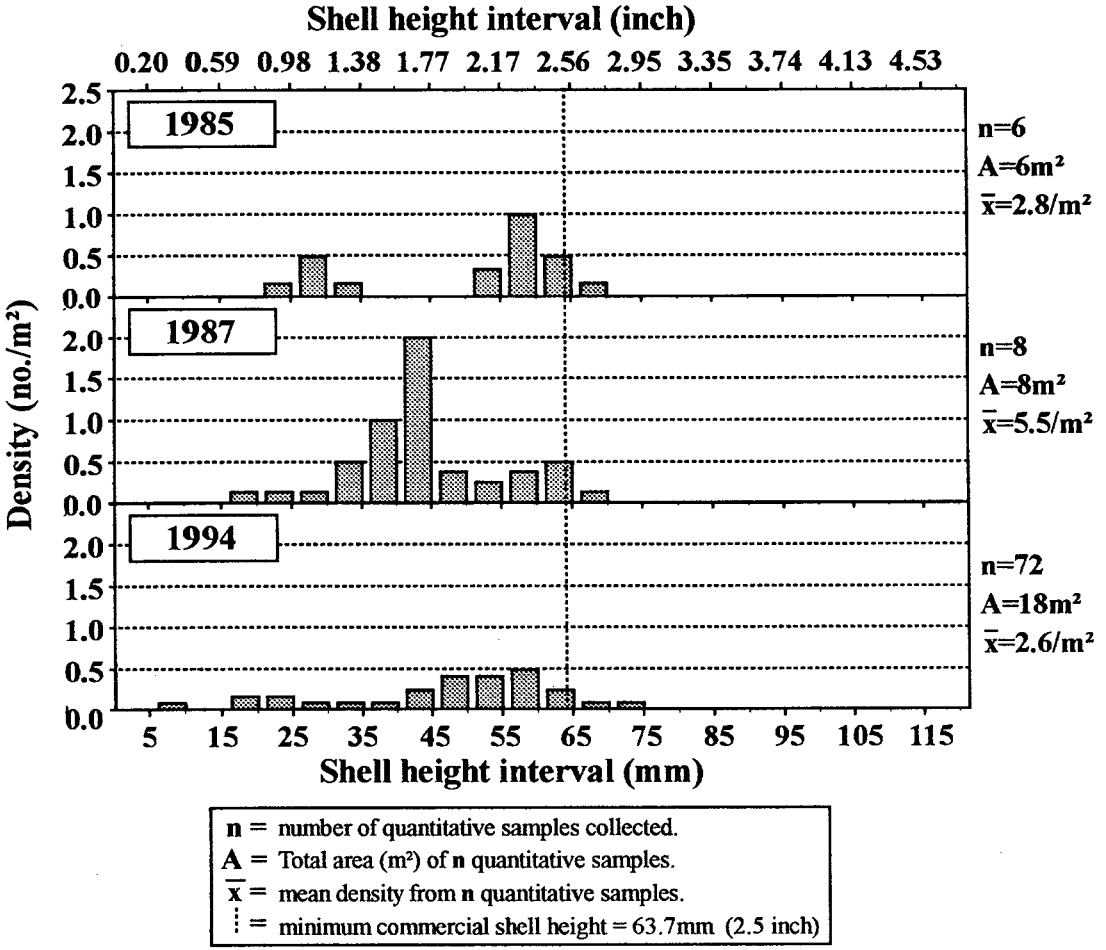


n = number of quantitative samples collected.
A = Total area (m²) of **n** quantitative samples.
$\bar{x}$ = mean density from **n** quantitative samples.
⋮ = minimum commercial shell height = 101.6 mm (4.0 inch)

Height Interval (mm)	Density (no./m²) 1985	1987	1994	Height Interval (inch)
5	0	0	0	0.20
10	0	0	0	0.39
15	0	0	0	0.59
20	0.12	0	0	0.79
25	0.00	0.38	0	0.98
30	0.00	0.00	0	1.18
35	0.00	0.13	0	1.38
40	0.12	0.13	0	1.57
45	0.00	0.00	0.06	1.77
50	0.00	0.00	0.00	1.97
55	0.00	0.25	0.00	2.17
60	0.00	0.00	0.22	2.36
65	0.00	0.25	0.44	2.56
70	0.00	0.00	0.50	2.76
75	0.00	0.00	0.50	2.95
80	0.12	0.00	0.44	3.15
85	0.12	0.00	0.33	3.35
90	0.25	0.25	0.33	3.54
95	0.61	0.13	0.28	3.74
100	0.37	0.13	0.44	3.94
105	0.61	0.13	0.00	4.13
110	0.25	0.13	0.06	4.33
115	0.12	0	0	4.53
120	0	0	0	4.72
Mean Density	**2.70**	**1.90**	**3.61**	

Figure D-12. Density distribution based on shell height of *Quadrula quadrula* (Mapleleaf) from Case-IH site (RM 488.5) in Reachl 15 of the Upper Mississippi River, 1985, 1987, and 1994.

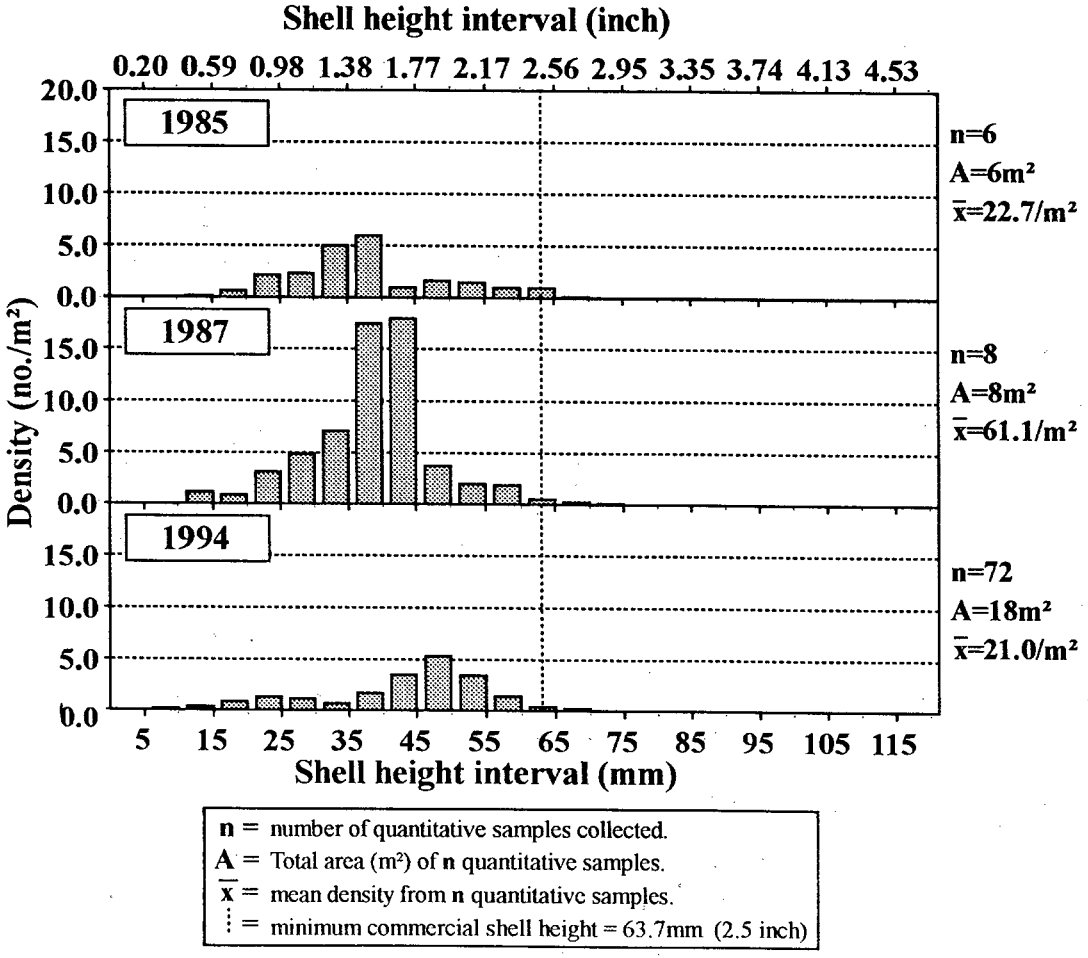
Species : *Quadrula quadrula*
Site : Case-IH (RM 488.5)
Year : 1985, 1987, and 1994



Height Interval (mm)	Density (no./m²) 1985	1987	1994	Height Interval (inch)
5	0	0	0	0.20
10	0	0	0.08	0.39
15	0	0	0.00	0.59
20	0	0.13	0.16	0.79
25	0.16	0.13	0.16	0.98
30	0.49	0.13	0.08	1.18
35	0.16	0.50	0.08	1.38
40	0.00	1.00	0.08	1.57
45	0.00	2.00	0.24	1.77
50	0.00	0.38	0.41	1.97
55	0.33	0.25	0.41	2.17
60	0.99	0.38	0.49	2.36
65	0.49	0.50	0.24	2.56
70	0.16	0.13	0.08	2.76
75	0	0	0.08	2.95
80	0	0	0	3.15
85	0	0	0	3.35
90	0	0	0	3.54
95	0	0	0	3.74
100	0	0	0	3.94
105	0	0	0	4.13
110	0	0	0	4.33
115	0	0	0	4.53
120	0	0	0	4.72
Mean Density	**2.80**	**5.50**	**2.61**	

Figure D-13. Density distribution based on shell length of *Quadrula pustulosa* (Pimpleback) from Case-IH site (RM 488.5) in Reach 15 of the Upper Mississippi River, 1985, 1987, and 1994.

Species : *Quadrula pustulosa*
Site : Case-IH (RM 488.5)
Year : 1985, 1987, and 1994



Height Interval (mm)	Density (no./m²) 1985	1987	1994	Height Interval (inch)
5	0	0	0	0.20
10	0	0	0.22	0.39
15	0.17	1.12	0.39	0.59
20	0.67	0.87	0.89	0.79
25	2.17	3.12	1.33	0.98
30	2.34	4.87	1.17	1.18
35	5.01	7.12	0.72	1.38
40	6.01	17.49	1.72	1.57
45	1.00	17.99	3.56	1.77
50	1.67	3.75	5.33	1.97
55	1.50	2.00	3.50	2.17
60	1.00	1.87	1.44	2.36
65	1.00	0.50	0.44	2.56
70	0.17	0.25	0.28	2.76
75	0	0.12	0	2.95
80	0	0	0	3.15
85	0	0	0	3.35
90	0	0	0	3.54
95	0	0	0	3.74
100	0	0	0	3.94
105	0	0	0	4.13
110	0	0	0	4.33
115	0	0	0	4.53
120	0	0	0	4.72
Mean Density	22.70	61.10	21.00	

Appendix E

Density distributions based on estimated age

Reach 15 of the Upper Mississippi River

Appendix E

Density distributions based on estimated age

Reach 15 of the Upper Mississippi River

Part I.

Sylvan Slough (RM 485.8)

Species: *Scientific* - Common (Abbreviation)

Amblema plicata - Threeridge (AmPl)

Megalonaias nervosa - Washboard (MeNe)

Quadrula quadrula - Mapleleaf (QuQu)

Quadrula metanevra - Monkeyface (QuMe)

Quadrula pustulosa - Pimpleback (QuPu)

Ellipsaria lineolata - Butterfly (ElLi)[1]

Obliquaria reflexa - Threehorn (ObRe)[1]

[1] - were not aged in 1994-95 survey, age calculated from shell length using age/length regression equations from 1987.

Figure E-1. Frequency histograms of density (no./m²) at age for selected unionid species from Sylvan Slough (RM 485.8) in Reach 15 of the Upper Mississippi River, 1994-95. Unionids were collected from 116 quantitative samples covering a surface area of 34 m².

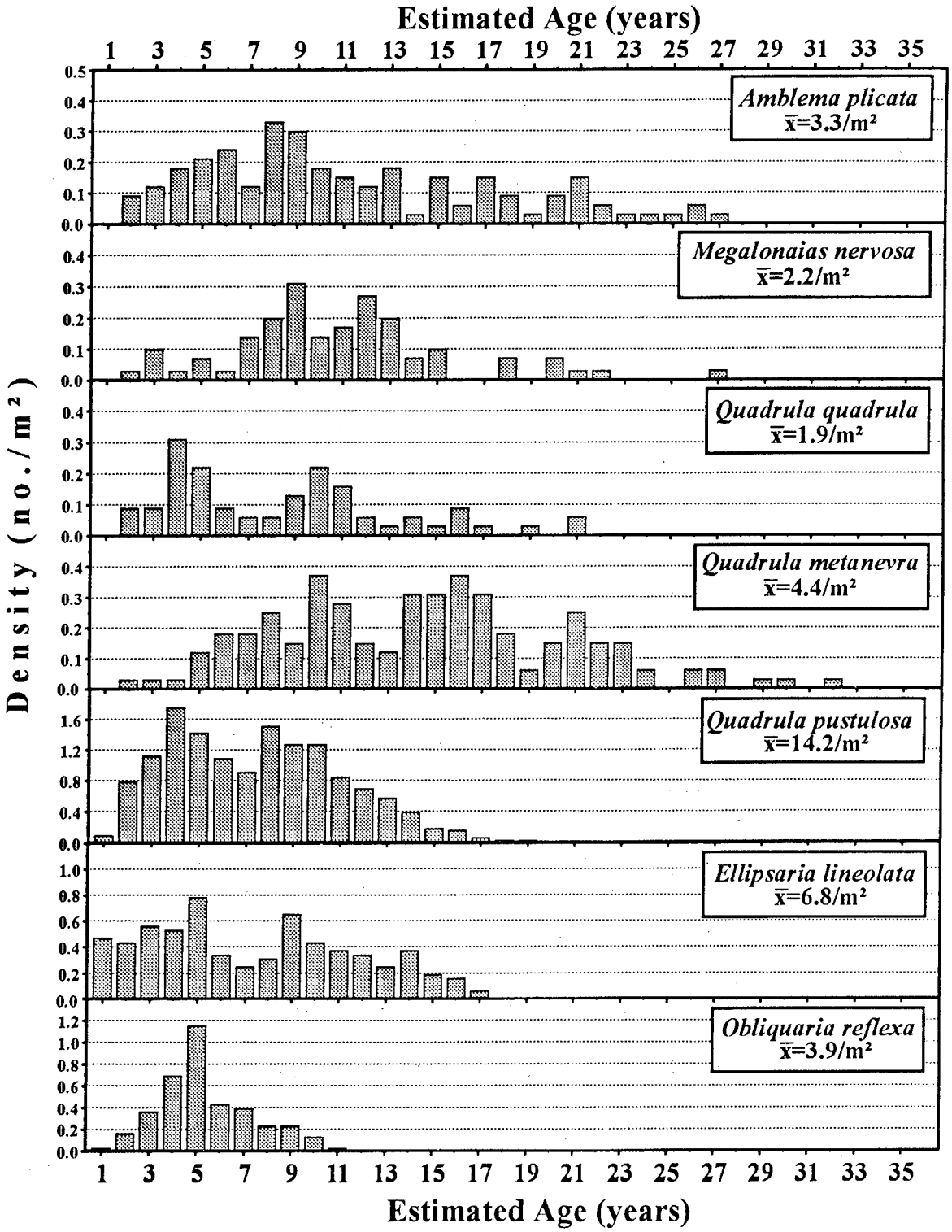


Table E-1. Density distributions based on estimated age for selected unionid species from Sylvan Slough (RM 485.8) in Reach 15 of the Upper Mississippi River, 1994-95. Unionids were collected from 116 quantitative samples covering a surface area of 34 m².

Age (yrs)	Density (no./m²)						
	AmPl	MeNe	QuQu	QuMe	QuPu	ElLi	ObRe
1	0	0	0	0	0.09	0.47	0.03
2	0.09	0.03	0.09	0.03	0.78	0.43	0.16
3	0.12	0.10	0.09	0.03	1.12	0.56	0.36
4	0.18	0.03	0.31	0.03	1.75	0.53	0.69
5	0.21	0.07	0.22	0.12	1.42	0.78	1.15
6	0.24	0.03	0.09	0.18	1.09	0.34	0.43
7	0.12	0.14	0.06	0.18	0.91	0.25	0.39
8	0.33	0.20	0.06	0.25	1.51	0.31	0.23
9	0.30	0.31	0.13	0.15	1.27	0.65	0.23
10	0.18	0.14	0.22	0.37	1.27	0.43	0.13
11	0.15	0.17	0.16	0.28	0.84	0.37	0.03
12	0.12	0.27	0.06	0.15	0.69	0.34	0
13	0.18	0.20	0.03	0.12	0.57	0.25	0
14	0.03	0.07	0.06	0.31	0.39	0.37	0
15	0.15	0.10	0.03	0.31	0.18	0.19	0
16	0.06	0.00	0.09	0.37	0.15	0.16	0
17	0.15	0.00	0.03	0.31	0.06	0.06	0
18	0.09	0.07	0.00	0.18	0.03	0	0
19	0.03	0.00	0.03	0.06	0.03	0	0
20	0.09	0.07	0.00	0.15	0	0	0
21	0.15	0.03	0.06	0.25	0	0	0
22	0.06	0.03	0.00	0.15	0	0	0
23	0.03	0.00	0.00	0.15	0	0	0
24	0.03	0.00	0.00	0.06	0	0	0
25	0.03	0.00	0.00	0.00	0	0	0
26	0.06	0.00	0	0.06	0	0	0
27	0.03	0.03	0	0.06	0	0	0
28	0	0	0	0.00	0	0	0
29	0	0	0	0.03	0	0	0
30	0	0	0	0.03	0	0	0
31	0	0	0	0.00	0	0	0
32	0	0	0	0.03	0	0	0
33	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0
Mean	**3.25**	**2.24**	**1.85**	**4.42**	**14.15**	**6.80**	**3.94**

Figure E-2. Frequency histograms of density (no./m²) at age for selected unionid species from Sylvan Slough (RM 485.8) in Reach 15 of the Upper Mississippi River, 1987. Unionids were collected from 8 quantitative samples covering a surface area of 8 m².

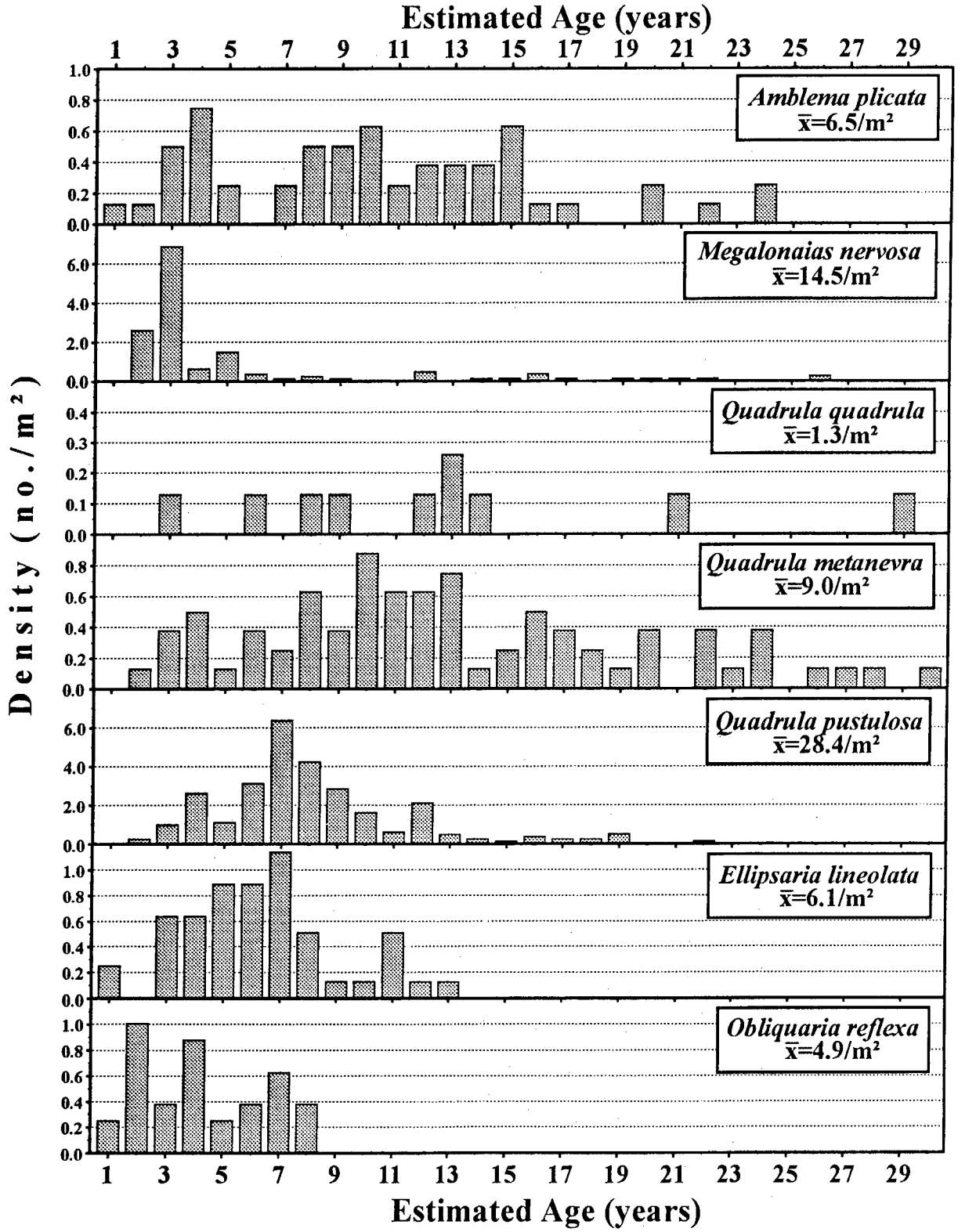


Table E-2. Density distributions based on estimated age for selected unionid species from Sylvan Slough (RM 485.8) in Reach 15 of the Upper Mississippi River, 1987. Unionids were collected from 8 quantitative samples covering a surface area of 8 m².

Age (yrs)	Density (no./m²)						
	AmPl	MeNe	QuQu	QuMe	QuPu	ElLi	ObRe
1	0.13	0	0	0	0	0.25	0.25
2	0.13	2.63	0	0.13	0.25	0.00	1.01
3	0.50	6.88	0.13	0.38	1.00	0.64	0.38
4	0.75	0.63	0.00	0.50	2.63	0.64	0.88
5	0.25	1.50	0.00	0.13	1.13	0.89	0.25
6	0.00	0.38	0.13	0.38	3.13	0.89	0.38
7	0.25	0.13	0.00	0.25	6.38	1.14	0.63
8	0.50	0.25	0.13	0.63	4.25	0.51	0.38
9	0.50	0.13	0.13	0.38	2.88	0.13	0
10	0.63	0.00	0.00	0.88	1.63	0.13	0
11	0.25	0.00	0.00	0.63	0.63	0.51	0
12	0.38	0.50	0.13	0.63	2.13	0.13	0
13	0.38	0.00	0.26	0.75	0.50	0.13	0
14	0.38	0.13	0.13	0.13	0.25	0.00	0
15	0.63	0.13	0.00	0.25	0.13	0	0
16	0.13	0.38	0.00	0.50	0.38	0	0
17	0.13	0.13	0.00	0.38	0.25	0	0
18	0.00	0.00	0.00	0.25	0.25	0	0
19	0.00	0.13	0.00	0.13	0.50	0	0
20	0.25	0.13	0.00	0.38	0.00	0	0
21	0.00	0.13	0.13	0.00	0.00	0	0
22	0.13	0.13	0.00	0.38	0.13	0	0
23	0.00	0.00	0.00	0.13	0	0	0
24	0.25	0.00	0.00	0.38	0	0	0
25	0	0.00	0.00	0.00	0	0	0
26	0	0.25	0.00	0.13	0	0	0
27	0	0	0.00	0.13	0	0	0
28	0	0	0.00	0.13	0	0	0
29	0	0	0.13	0.00	0	0	0
30	0	0	0	0.13	0	0	0
Mean	**6.50**	**14.50**	**1.30**	**9.00**	**28.40**	**6.10**	**4.90**

Part II.

Case-IH (488.5)

Species: *Scientific* - Common (Abbreviation)

Amblema plicata - Threeridge (AmPl)

Megalonaias nervosa - Washboard (MeNe)

Quadrula quadrula - Mapleleaf (QuQu)

Quadrula metanevra - Monkeyface (QuMe)

Quadrula pustulosa - Pimpleback (QuPu)

Ellipsaria lineolata - Butterfly (ElLi)[1]

Obliquaria reflexa - Threehorn (ObRe)[1]

[1] - were not aged in 1994-95 survey, age calculated from shell length using age/length regression equations from 1987.

Figure E-3. Frequency histograms of density (no./m²) at age for selected unionid species from Case-IH (RM 488.5) in Reach 15 of the Upper Mississippi River, 1994. Unionids were collected from 72 quantitative samples covering a surface area of 18 m².

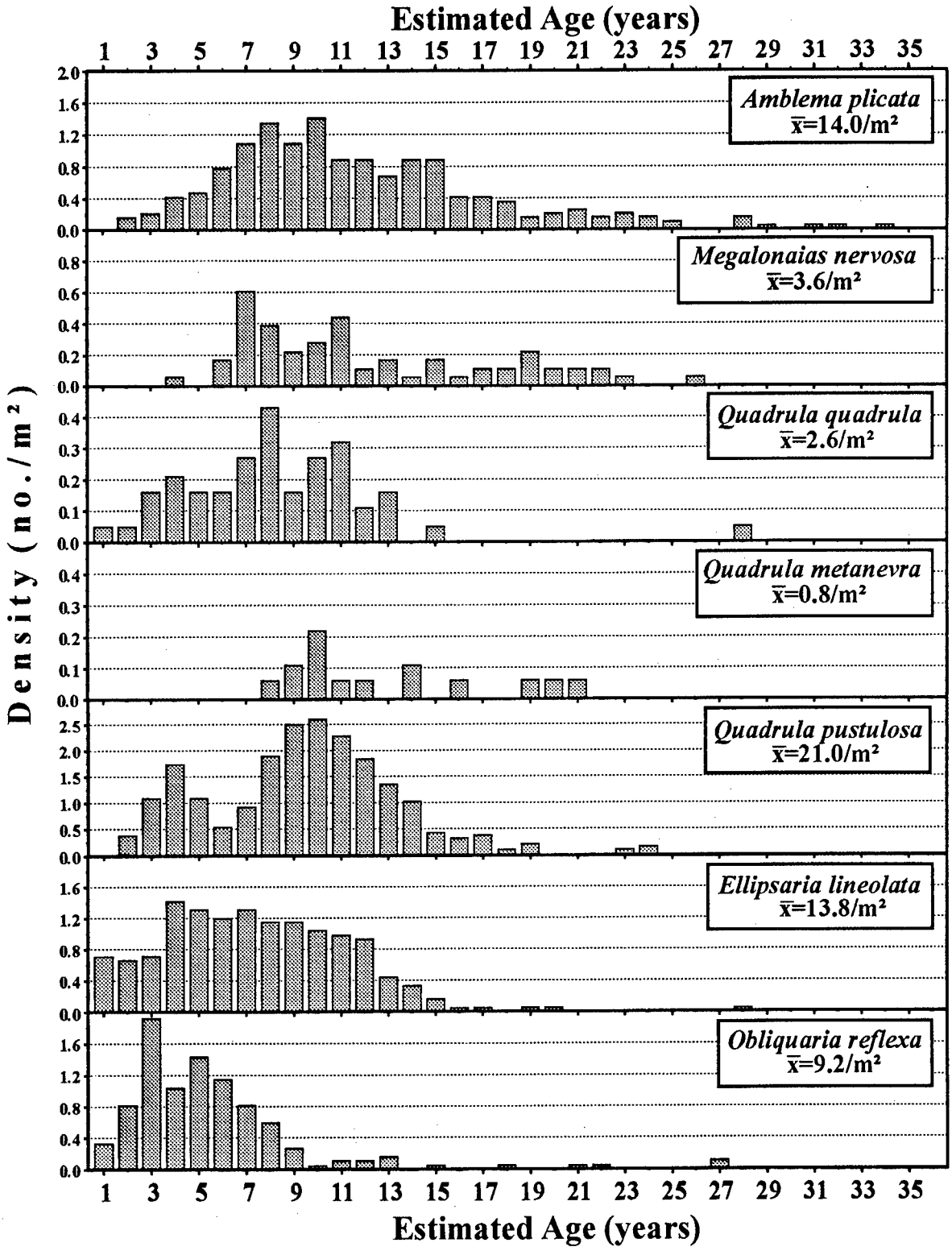


Table E-3. Density distributions based on estimated age for selected unionid species from Case-IH (RM 488.5) in Reach 15 of the Upper Mississippi River, 1994. Unionids were collected from 72 quantitative samples covering a surface area of 18 m².

Age (yrs)	Density (no./m²)						
	AmPl	MeNe	QuQu	QuMe	QuPu	ElLi	ObRe
1	0	0	0.05	0	0	0.71	0.33
2	0.16	0	0.05	0	0.38	0.66	0.82
3	0.21	0	0.16	0	1.09	0.71	1.92
4	0.42	0.06	0.21	0	1.74	1.42	1.04
5	0.47	0.00	0.16	0	1.09	1.31	1.43
6	0.78	0.17	0.16	0	0.54	1.20	1.15
7	1.09	0.61	0.27	0	0.92	1.31	0.82
8	1.35	0.39	0.43	0.06	1.90	1.15	0.60
9	1.09	0.22	0.16	0.11	2.50	1.15	0.27
10	1.41	0.28	0.27	0.22	2.60	1.04	0.05
11	0.88	0.44	0.32	0.06	2.28	0.98	0.11
12	0.88	0.11	0.11	0.06	1.84	0.93	0.11
13	0.68	0.17	0.16	0.00	1.36	0.44	0.16
14	0.88	0.06	0.00	0.11	1.03	0.33	0.00
15	0.88	0.17	0.05	0.00	0.43	0.16	0.05
16	0.42	0.06	0.00	0.06	0.33	0.05	0.00
17	0.42	0.11	0.00	0.00	0.38	0.05	0.00
18	0.36	0.11	0.00	0.00	0.11	0.00	0.05
19	0.16	0.22	0.00	0.06	0.22	0.05	0.00
20	0.21	0.11	0.00	0.06	0.00	0.05	0.00
21	0.26	0.11	0.00	0.06	0.00	0.00	0.05
22	0.16	0.11	0.00	0	0.00	0.00	0.05
23	0.21	0.06	0.00	0	0.11	0.00	0.00
24	0.16	0.00	0.00	0	0.16	0.00	0.00
25	0.10	0.00	0.00	0	0	0.00	0.00
26	0.00	0.06	0.00	0	0	0.00	0.00
27	0.00	0	0.00	0	0	0.00	0.11
28	0.16	0	0.05	0	0	0.05	0
29	0.05	0	0	0	0	0	0
30	0.00	0	0	0	0	0	0
31	0.05	0	0	0	0	0	0
32	0.05	0	0	0	0	0	0
33	0.00	0	0	0	0	0	0
34	0.05	0	0	0	0	0	0
35	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0
Mean	**14.00**	**3.61**	**2.61**	**0.83**	**21.00**	**13.78**	**9.17**

Figure E-4. Frequency histograms of density (no./m²) at age for selected unionid species from Case-IH (RM 488.5) in Reach 15 of the Upper Mississippi River, 1987. Unionids were collected from 8 quantitative samples covering a surface area of 8 m².

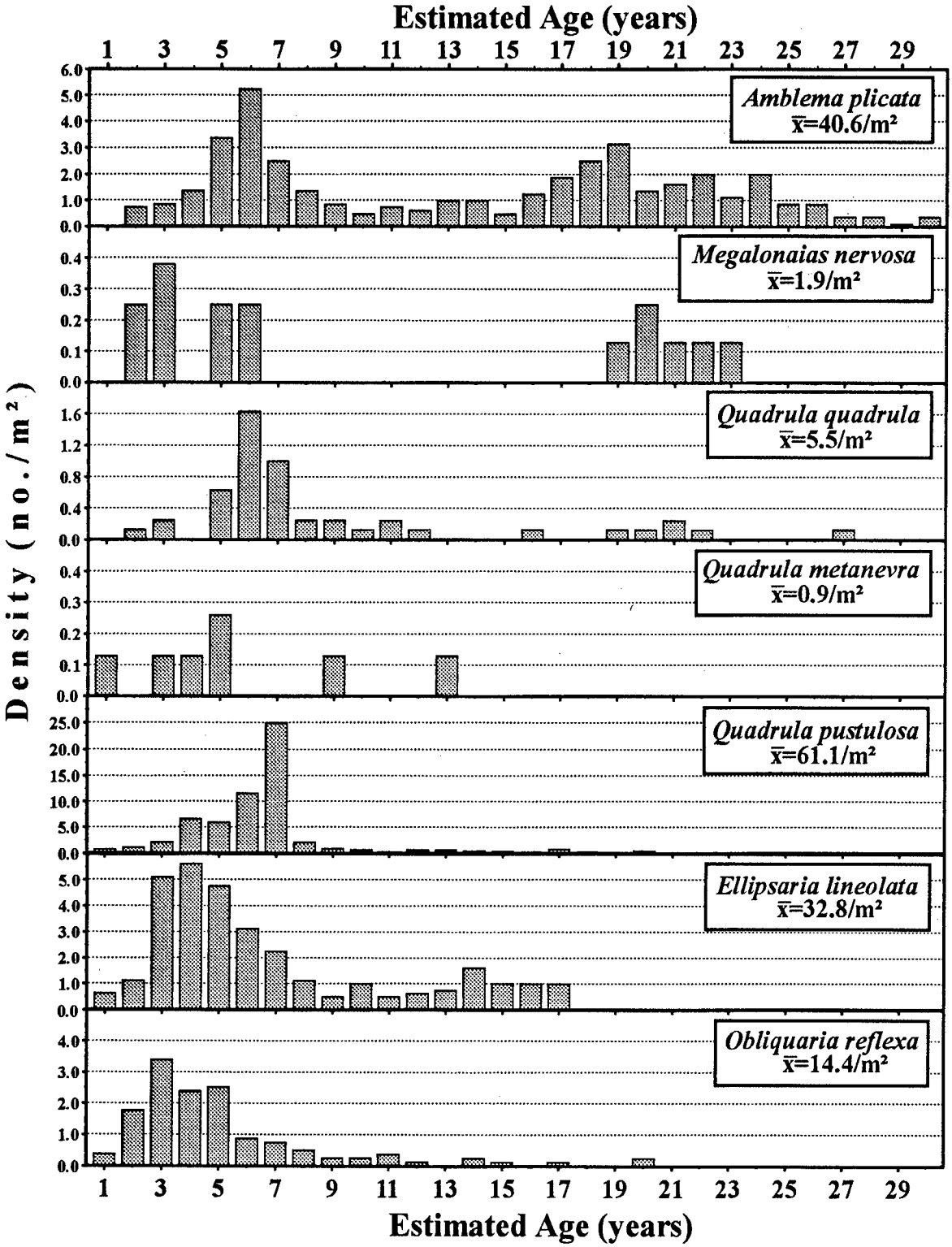


Table E-4. Density distributions based on estimated age for selected unionid species from Case-IH (RM 488.5) in Reach 15 of the Upper Mississippi River, 1987. Unionids were collected from 8 quantitative samples covering a surface area of 8 m².

Age (yrs)	Density (no./m²)						
	AmPl	MeNe	QuQu	QuMe	QuPu	ElLi	ObRe
1	0	0	0	0.13	0.75	0.63	0.38
2	0.75	0.25	0.13	0.00	1.13	1.13	1.77
3	0.87	0.38	0.25	0.13	2.13	5.13	3.41
4	1.37	0.00	0.00	0.13	6.64	5.63	2.40
5	3.37	0.25	0.63	0.26	6.01	4.76	2.53
6	5.25	0.25	1.63	0.00	11.64	3.13	0.88
7	2.50	0.00	1.00	0.00	24.92	2.25	0.76
8	1.37	0.00	0.25	0.00	2.13	1.13	0.51
9	0.87	0.00	0.25	0.13	0.88	0.50	0.25
10	0.50	0.00	0.13	0.00	0.63	1.00	0.25
11	0.75	0.00	0.25	0.00	0.25	0.50	0.38
12	0.62	0.00	0.13	0.00	0.63	0.63	0.13
13	1.00	0.00	0.00	0.13	0.63	0.75	0.00
14	1.00	0.00	0.00	0	0.50	1.63	0.25
15	0.50	0.00	0.00	0	0.38	1	0.13
16	1.25	0.00	0.13	0	0.25	1	0.00
17	1.87	0.00	0.00	0	0.75	1	0.13
18	2.50	0.00	0.00	0	0.25	0	0.00
19	3.12	0.13	0.13	0	0.00	0	0.00
20	1.37	0.25	0.13	0	0.50	0	0.25
21	1.62	0.13	0.25	0	0	0	0
22	2.00	0.13	0.13	0	0	0	0
23	1.12	0.13	0.00	0	0	0	0
24	2.00	0	0.00	0	0	0	0
25	0.87	0	0.00	0	0	0	0
26	0.87	0	0.00	0	0	0	0
27	0.37	0	0.13	0	0	0	0
28	0.37	0	0	0	0	0	0
29	0.12	0	0	0	0	0	0
30	0.37	0	0	0	0	0	0
Mean	**40.60**	**1.90**	**5.50**	**0.90**	**61.10**	**32.80**	**14.40**

Part III.

Illiniwek (RM 492.4)

Species: *Scientific* - Common (Abbreviation)

Amblema plicata - Threeridge (AmPl)

Megalonaias nervosa - Washboard (MeNe)

Quadrula quadrula - Mapleleaf (QuQu)

Quadrula metanevra - Monkeyface (QuMe)

Quadrula pustulosa - Pimpleback (QuPu)

Ellipsaria lineolata - Butterfly (ElLi)[1]

Obliquaria reflexa - Threehorn (ObRe)[1]

[1] - were not aged in 1994-95 survey, age calculated from shell length using age/length regression equations from 1987.

Figure E-5. Frequency histograms of density (no./m²) at age for selected unionid species from Illiniwek (RM 492.4) in Reach 15 of the Upper Mississippi River, 1994-95. Unionids were collected from 98 quantitative samples covering a surface area of 29 m².

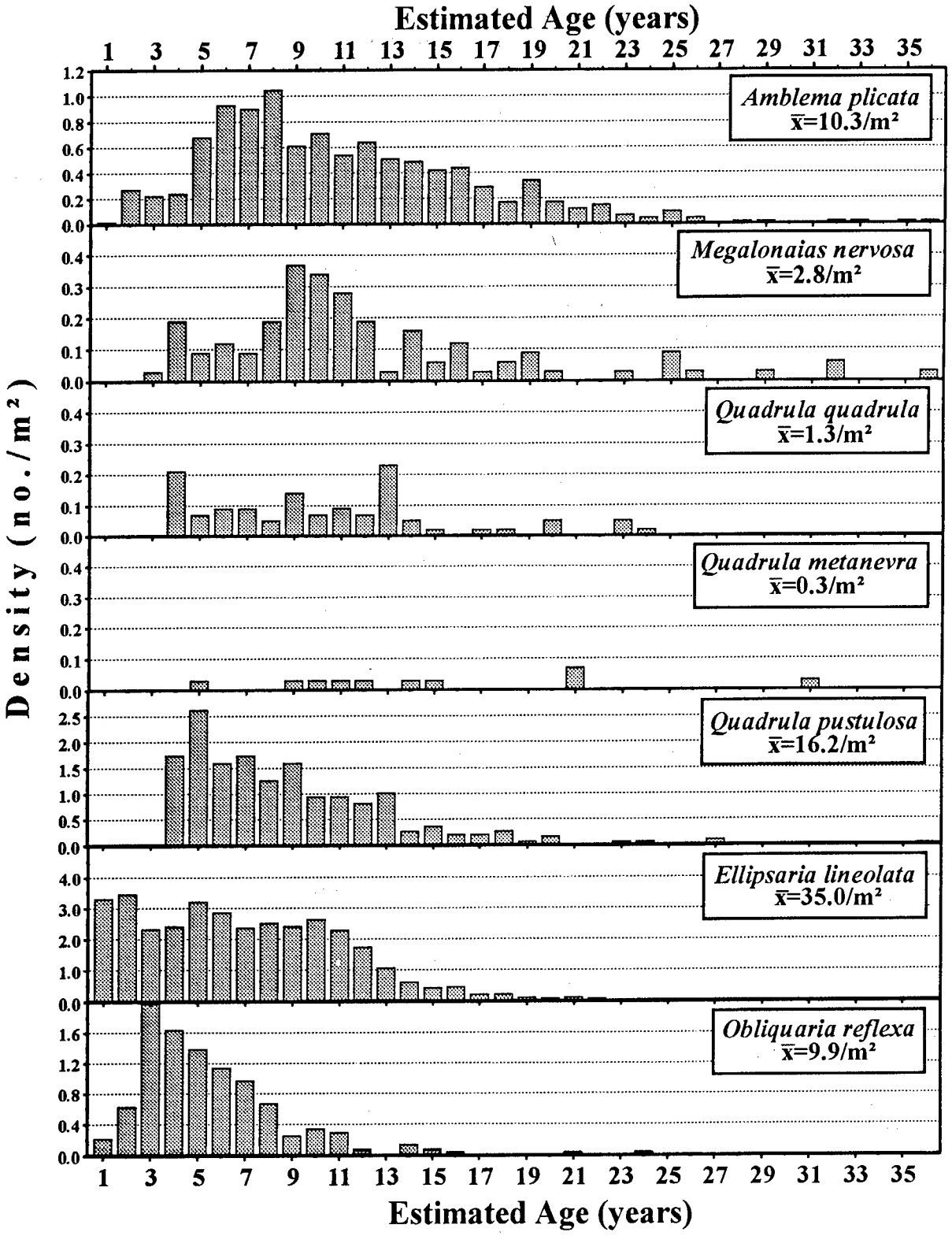


Table E-5. Density distributions based on estimated age for selected unionid species from Illiniwek (RM 492.4) in Reach 15 of the Upper Mississippi River, 1994-95. Unionids were collected from 98 quantitative samples covering a surface area of 29 m².

Age (yrs)	Density (no./m²)						
	AmPl	MeNe	QuQu	QuMe	QuPu	ElLi	ObRe
1	0.02	0	0	0	0	3.30	0.21
2	0.27	0	0	0	0	3.46	0.63
3	0.22	0.03	0	0	0.03	2.33	1.98
4	0.24	0.19	0.21	0	1.74	2.41	1.64
5	0.68	0.09	0.07	0.03	2.62	3.22	1.39
6	0.93	0.12	0.09	0.00	1.60	2.87	1.14
7	0.90	0.09	0.09	0.00	1.74	2.37	0.97
8	1.05	0.19	0.05	0.00	1.26	2.52	0.67
9	0.61	0.37	0.14	0.03	1.60	2.41	0.25
10	0.71	0.34	0.07	0.03	0.95	2.64	0.34
11	0.54	0.28	0.09	0.03	0.95	2.29	0.29
12	0.64	0.19	0.07	0.03	0.82	1.75	0.08
13	0.51	0.03	0.23	0.00	1.02	1.09	0.00
14	0.49	0.16	0.05	0.03	0.27	0.62	0.13
15	0.42	0.06	0.02	0.03	0.37	0.43	0.08
16	0.44	0.12	0.00	0.00	0.20	0.47	0.04
17	0.29	0.03	0.02	0.00	0.20	0.23	0.00
18	0.17	0.06	0.02	0.00	0.27	0.23	0.00
19	0.34	0.09	0.00	0.00	0.07	0.12	0.00
20	0.17	0.03	0.05	0.00	0.17	0.08	0.00
21	0.12	0.00	0.00	0.07	0.00	0.12	0.04
22	0.15	0.00	0.00	0.00	0.00	0.08	0.00
23	0.07	0.03	0.05	0.00	0.07	0	0.00
24	0.05	0.00	0.02	0.00	0.07	0	0.04
25	0.10	0.09	0	0.00	0.00	0	0
26	0.05	0.03	0	0.00	0.00	0	0
27	0.00	0.00	0	0.00	0.10	0	0
28	0.02	0.00	0	0.00	0.00	0	0
29	0.02	0.03	0	0.00	0.00	0	0
30	0.00	0.00	0	0.00	0.00	0	0
31	0.00	0.00	0	0.03	0.00	0	0
32	0.02	0.06	0	0	0.00	0	0
33	0.02	0.00	0	0	0.00	0	0
34	0.00	0.00	0	0	0.00	0	0
35	0.02	0.00	0	0	0.00	0	0
36	0.02	0.03	0	0	0.03	0	0
Mean	**10.34**	**2.77**	**1.33**	**0.33**	**16.17**	**35.02**	**9.93**

Appendix F

Unionid mussel recruitment

Reach 15 of the Upper Mississippi River

Appendix F

Unionid mussel recruitment

Reach 15 of the Upper Mississippi River

Figure F-1. Recruitment of unionid mussel species at three sites in Reach 15 of the Upper Mississippi River, 1994-95. Length-frequency distributions (Appendix C) were used to calculate percentage (%) and density (no./m²) of individuals within the specified size range.

Species	Recruitment								
	Size (mm)	Percentage (%)				Density (no./m²)			
		Sylvan Slough	Case	Illiniwek	Mean	Sylvan Slough	Case	Illiniwek	Mean
Amblema plicata	< 30	7.42	3.96	6.59	**5.99**	0.24	0.56	0.68	**0.49**
Megalonaias nervosa	< 30	1.52	0.00	0.00	**0.51**	0.03	0.00	0.00	**0.01**
Quadrula metanevra	< 30	1.40	0.00	0.00	**0.47**	0.06	0.00	0.00	**0.02**
Quadrula pustulosa	< 30	30.34	17.73	23.93	**24.00**	4.30	3.72	3.90	**3.97**
Quadrula quadrula	< 30	19.68	14.89	16.67	**17.08**	0.36	0.40	0.22	**0.33**
Ellipsaria lineolata	< 30	9.59	4.03	9.54	**7.72**	0.65	0.56	3.34	**1.52**
Leptodea fragilis	< 30	21.83	56.76	23.88	**34.16**	0.37	1.17	0.92	**0.82**
Obliquaria reflexa	< 15	6.99	2.46	4.76	**4.74**	0.21	0.22	0.48	**0.30**
Truncilla truncata	< 15	10.91	11.80	44.83	**22.51**	0.93	2.13	1.42	**1.49**
Truncilla donaciformis	< 10	31.43	2.78	0.00	**11.40**	1.41	0.06	0.00	**0.49**

Figure F-2. Recruitment of unionid mussel species at Sylvan Slough (RM 485.8) in Reach 15 of the Upper Mississippi River, 1983, 1985, 1987, and 1994-95. Length-frequency distributions (Appendix C) were used to calculate percentage (%) and density (no./m²) of individuals within the specified size range.

Species	Recruitment										
	Size (mm)	Percentage (%)					Density (no./m²)				
		1983	1985	1987	1994-95	Mean	1983	1985	1987	1994-95	Mean
Amblema plicata	< 30	0.00	3.84	9.61	7.42	**5.22**	0.00	0.38	0.64	0.24	**0.32**
Megalonaias nervosa	< 30	0.00	0.93	3.45	1.52	**1.48**	0.00	0.13	0.50	0.03	**0.17**
Quadrula metanevra	< 30	0.00	7.17	2.78	1.40	**2.84**	0.00	0.12	0.25	0.06	**0.11**
Quadrula pustulosa	< 30	16.86	16.45	9.72	30.34	**18.34**	3.50	3.27	2.77	4.30	**3.46**
Quadrula quadrula	< 30	9.09	1.89	10.00	19.68	**10.17**	0.25	0.13	0.13	0.36	**0.22**
Ellipsaria lineolata	< 30	0.00	2.38	4.17	9.59	**4.04**	0.00	0.12	0.25	0.65	**0.26**
Leptodea fragilis	< 30	5.40	3.70	10.98	21.83	**10.48**	0.50	0.37	1.14	0.37	**0.60**
Obliquaria reflexa	< 15	0.00	3.13	2.56	6.99	**3.17**	0.00	0.13	0.13	0.21	**0.12**
Truncilla truncata	< 15	0.00	0.00	0.63	10.91	**2.89**	0.00	0.00	0.13	0.93	**0.27**
Truncilla donaciformis	< 10	0.00	0.00	3.92	31.43	**8.84**	0.00	0.00	0.26	1.41	**0.42**

Figure F-3. Recruitment of unionid mussel species at Case-IH (RM 488.5) in Reach 15 of the Upper Mississippi River, 1985, 1987, and 1994. Length-frequency distributions (Appendix C) were used to calculate percentage (%) and density (no./m²) of individuals within the specified size range.

Species	Recruitment								
	Size (mm)	Percentage (%)				Density (no./m²)			
		1985	1987	1994	Mean	1985	1987	1994	Mean
Amblema plicata	< 30	3.48	5.23	3.96	4.22	0.23	2.12	0.56	0.97
Megalonaias nervosa	< 30	4.55	0.00	0.00	1.52	0.66	0.00	0.00	0.22
Quadrula metanevra	< 30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quadrula pustulosa	< 30	21.33	14.73	17.73	17.93	6.06	8.99	3.72	6.26
Quadrula quadrula	< 30	5.88	4.55	14.89	8.44	0.08	0.25	0.40	0.24
Ellipsaria lineolata	< 30	1.08	4.59	4.03	3.23	0.07	1.51	0.56	0.71
Leptodea fragilis	< 30	11.58	7.12	56.76	25.15	1.20	2.38	1.17	1.58
Obliquaria reflexa	< 15	0.00	0.00	2.46	0.82	0.00	0.00	0.22	0.07
Truncilla truncata	< 15	0.00	0.36	11.80	4.05	0.00	0.25	2.13	0.79
Truncilla donaciformis	< 10	0.00	2.98	2.78	1.92	0.00	0.26	0.06	0.11

Appendix G

Commercial Species Age and Growth

Reach 15 of the Upper Mississippi River

Appendix G

Commercial Species Age and Growth

Reach15 of the Upper Mississippi River

Part I.

Summary tables on age and growth of unionid mussels from Reach 15 of the Upper Mississippi River.

Table G-1 : Number of years for five mussel species from Reach 15 of the Upper Mississippi River to reach minimum commercial size limit. Age determination based on polynomial regression formulas (Table G-3).

Species	Minimum commercial size[1]		Years to reach minimum commercial size	
	(inch)	(mm)	1994-95	1987
Amblema plicata (Threeridge)	2.75	69.85	21	25
Megalonaias nervosa (Washboard)	4.00	101.60	24	25
Quadrula metanevra (Monkeyface)	2.50	63.50	----	21
Quadrula pustulosa (Pimpleback)	2.50	63.50	19	20
Quadrula quadrula (Mapleleaf)	2.50	63.50	19	20

[1] - measured from the center of the hinge side and at a right angle across the shell to the outer edge (shell height).

Table G-2 : Estimated number of years for five mussel species to reach sexual maturity in Reach 15 of the Upper Mississippi River. Values based on observed decrease in distance between growth bands on individual mussels collected in 1994-95.

Species	n	Estimated years to maturity		
		Mean	Std. Dev.	Range
Amblema plicata (Threeridge)	78	**8.19**	1.37	6 - 12
Megalonaias nervosa (Washboard)	29	**8.17**	1.10	6 - 10
Quadrula metanevra (Monkeyface)	12	**7.17**	1.19	5 - 9
Quadrula pustulosa (Pimpleback)	38	**7.58**	1.81	6 - 11
Quadrula quadrula (Mapleleaf)	28	**8.36**	2.00	8 - 11

Table G-3. Formulas to calculate unionid age (yrs.) from shell length or height (mm) for species collected in Reach 15 of the Upper Mississippi River in (a) 1994-95 and (b) 1987. All relationships were best described by a third order polynomial regression formula.

Example: Calculate the age of a *Megalonaias nervosa* collected in 1994-95 with a height of 88.9 mm (3.5 inch).

Calculations: $y = 0.0000688x^3 - 0.0083326x^2 + 0.4076798x - 3.1385823$

$y = 0.0000688(88.9)^3 - 0.0083326(88.0)^2 + 0.4076798(88.9) - 3.1385823$

$y = 0.0000688(702595.37) - 0.0083326(7903.21) + 0.4076798(88.9) - 3.1385823$

$y = 48.3385615 - 65.8542876 + 36.2427342 - 3.1385823$

$y = 15.59$ years old

(a) 1994-95

Species	y	x	Formula	r^2
Amblema plicata	age	length	$y = 0.0000611x^3 - 0.0063227x^2 + 0.3293202x - 2.0603603$	0.9820
	age	height	$y = 0.0001352x^3 - 0.0103458x^2 + 0.3845092x - 1.6220988$	0.9861
Megalonaias nervosa	age	length	$y = 0.0000150x^3 - 0.0017899x^2 + 0.1043503x + 0.8485574$	0.9817
	age	height	$y = 0.0000688x^3 - 0.0083326x^2 + 0.4076798x - 3.1385823$	0.9513
Quadrula pustulosa	age	length	$y = 0.0000801x^3 - 0.0037934x^2 + 0.2010223x - 0.2367326$	0.9832
	age	height	$y = 0.0001789x^3 - 0.0118251x^2 + 0.3874485x - 1.1206431$	0.9652
Quadrula quadrula	age	length	$y = 0.0000611x^3 - 0.0063227x^2 + 0.3293202x - 2.0603603$	0.9820
	age	height	$y = 0.0000648x^3 + 0.0017484x^2 - 0.1600863x + 5.4257652$	0.9448

(b) 1987

Species	y	x	Formula	r^2
Amblema plicata	age	length	$y = -0.0000268x^3 + 0.0096861x^2 - 0.4511657x + 7.3304427$	0.9448
	age	height	$y = -0.0000463x^3 + 0.0153635x^2 - 0.6001301x + 7.8939737$	0.9467
Megalonaias nervosa	age	length	$y = 0.0000156x^3 - 0.0021194x^2 + 0.1768499x - 2.1064416$	0.9412
	age	height	$y = 0.0000410x^3 - 0.0037773x^2 + 0.2273856x - 1.7508804$	0.9497
Quadrula metanevra	age	length	$y = 0.0001713x^3 - 0.0156912x^2 + 0.6016140x - 5.0779275$	0.9838
	age	height	$y = 0.0004565x^3 - 0.0414700x^2 + 1.3772656x - 12.7058843$	0.9834
Quadrula pustulosa	age	length	$y = 0.0002077x^3 - 0.0169617x^2 + 0.6108890x - 4.5812617$	0.9818
	age	height	$y = 0.0002409x^3 - 0.0201669x^2 + 0.7151071x - 5.4470434$	0.9741
Quadrula quadrula	age	length	$y = 0.0001973x^3 - 0.0209885x^2 + 0.8787901x - 9.2126875$	0.8617
	age	height	$y = 0.0000628x^3 + 0.0013627x^2 - 0.0559941x + 2.3033227$	0.8073
Ellipsaria lineolata	age	length	$y = -0.0000249x^3 + 0.0089175x^2 - 0.4059395x + 5.6305060$	0.9126
	age	height	$y = -0.0000576x^3 + 0.0142301x^2 - 0.4725642x + 4.9521332$	0.9092
Obliquaria reflexa	age	length	$y = 0.0004491x^3 - 0.0351957x^2 + 1.0376130x - 8.6958402$	0.9760
	age	height	$y = 0.0004641x^3 - 0.0269657x^2 + 0.6638447x - 4.1366390$	0.9845

Table G-4. Regression equation parameters of growth curves (Figures 1-5) for unionid species collected in Reach 15 of the Upper Mississippi River in (a) 1994-95 and (b) 1987. Formulas can be used to calculate morphological shell measurements (mm) from unionid age (yrs.). All relationships were best described by a third order polynomial regression formula.

(a) 1994-95

Species	y	x	Formula	r^2
Amblema plicata	length	age	$y = 0.0050071x^3 - 0.3666344x^2 + 9.8249057x - 0.4260532$	0.9912
	width	age	$y = 0.0039842x^3 - 0.2602081x^2 + 5.8831218x + 0.8669406$	0.9789
	height	age	$y = 0.0045958x^3 - 0.3191360x^2 + 7.9720117x + 0.7129795$	0.9898
Megalonaias nervosa	length	age	$y = 0.0177900x^3 - 0.9967481x^2 + 19.9961039x - 9.2124276$	0.9817
	width	age	$y = 0.0062956x^3 - 0.3839674x^2 + 8.1506566x - 5.9351060$	0.9518
	height	age	$y = 0.0120926x^3 - 0.7049751x^2 + 14.4179442x - 8.6804480$	0.9752
Quadrula pustulosa	length	age	$y = 0.0095563x^3 - 0.4591499x^2 + 8.7732342x - 1.6112619$	0.9930
	width	age	$y = 0.0062383x^3 - 0.3273931x^2 + 6.0829175x - 1.9140641$	0.9904
	height	age	$y = 0.0057603x^3 - 0.3751007x^2 + 8.2306743x - 1.7984754$	0.9927
Quadrula quadrula	length	age	$y = 0.0051816x^3 - 0.3269566x^2 + 8.1284370x + 2.9573194$	0.9741
	width	age	$y = 0.0059529x^3 - 0.3206641x^2 + 6.0501791x + 0.5701078$	0.8928
	height	age	$y = 0.0076875x^3 - 0.4373603x^2 + 8.9145035x - 1.4862868$	0.9570

(b) 1987

Species	y	x	Formula	r^2
Amblema plicata	length	age	$y = 0.0068550x^3 - 0.4318429x^2 + 9.7916577x + 3.2610581$	0.9904
	width	age	$y = 0.0035412x^3 - 0.2238239x^2 + 5.0539655x + 4.2486195$	0.9908
	height	age	$y = 0.0052136x^3 - 0.3297364x^2 + 7.4764151x + 4.6248189$	0.9908
Megalonaias nervosa	length	age	$y = 0.0109224x^3 - 0.6825639x^2 + 15.5587462x + 5.0508338$	0.9830
	width	age	$y = 0.0038476x^3 - 0.2468855x^2 + 5.8132082x + 3.0244842$	0.9851
	height	age	$y = 0.0069224x^3 - 0.4460882x^2 + 10.5656144x + 4.6659580$	0.9845
Quadrula metanevra	length	age	$y = 0.0047743x^3 - 0.3053982x^2 + 7.2113570x + 10.6592964$	0.9737
	width	age	$y = 0.0023107x^3 - 0.1524142x^2 + 3.8090437x + 6.9840649$	0.9725
	height	age	$y = 0.0041474x^3 - 0.2597647x^2 + 5.8559550x + 13.9737817$	0.9705
Quadrula pustulosa	length	age	$y = 0.0062338x^3 - 0.3614091x^2 + 7.6985955x + 4.3316920$	0.9951
	width	age	$y = 0.0036749x^3 - 0.2213104x^2 + 4.8644087x + 3.3442995$	0.9937
	height	age	$y = 0.0056265x^3 - 0.3372531x^2 + 7.4101475x + 4.1748952$	0.9940
Quadrula quadrula	length	age	$y = 0.0061609x^3 - 0.4005523x^2 + 8.9274096x + 5.1135483$	0.9762
	width	age	$y = 0.0034844x^3 - 0.2238107x^2 + 4.8979279x + 3.8328803$	0.9724
	height	age	$y = 0.0060794x^3 - 0.3782481x^2 + 8.0639853x + 3.1150318$	0.9596
Ellipsaria lineolata	length	age	$y = 0.0206120x^3 - 0.8801632x^2 + 13.1422716x + 5.3824389$	0.9735
	width	age	$y = 0.0086633x^3 - 0.3699364x^2 + 5.6840818x - 0.1292106$	0.9736
	height	age	$y = 0.0165539x^3 - 0.7072558x^2 + 10.6173476x + 2.3427725$	0.9731
Obliquaria reflexa	length	age	$y = 0.0157802x^3 - 0.06259111x^2 + 8.6071230x + 9.6129379$	0.9911
	width	age	$y = 0.0134031x^3 - 0.5317640x^2 + 7.4484997x + 6.9729323$	0.9914
	height	age	$y = 0.0089603x^3 - 0.3563955x^2 + 4.9559685x + 4.4767819$	0.9926

Table G-5. Regression equation parameters of morphological measurements from mussels collected at Illiniwek site (RM 492.4), 1994-95. The relationship between morphological measurements were best described by a power regression equation (y = ax^b). Equation parameters are as follows : y = dependent variable; x = independent variable; a = y intercept; b = regression coefficient (slope); r^2 = coefficient of determination; and n = number of individuals plotted.

Example: Calculate the shell width and height of an *Amblema plicata* (Three ridge) with a shell length of 92.56 mm. (y = ax^b)
width = 0.8195 × 92.56^0.9065 = **49.67 mm** ÷ 25.4 mm/inch = **1.96 inch**
height = 1.0722 × 92.56^0.9302 = **72.35 mm** ÷ 25.4 mm/inch = **2.85 inch**

Species	y	x	a	b	r^2	n
Amblema plicata	width	length	0.8195	0.9065	0.9649	167
	height	length	1.0722	0.9302	0.9827	101
	length	width	1.4253	1.0643	0.9649	167
	height	width	1.3696	1.0131	0.9610	101
	length	height	0.9971	1.0565	0.9827	101
	width	height	0.8514	0.9486	0.9610	101
Ellipsaria lineolata	width	length	0.1601	1.2247	0.9016	565
	height	length	0.5743	1.0728	0.9798	173
	length	width	5.6614	0.7362	0.9016	565
	height	width	3.2606	0.8392	0.9415	173
	length	height	1.7949	0.9133	0.9798	173
	width	height	0.3144	1.1219	0.9415	173
Megalonaias nervosa	width	length	0.3771	1.0112	0.9255	70
	height	length	0.5610	1.0513	0.9883	34
	length	width	3.4470	0.9153	0.9255	70
	height	width	2.1239	0.9548	0.9483	34
	length	height	1.8163	0.9401	0.9883	34
	width	height	0.5710	0.9932	0.9483	34
Obliquaria reflexa	width	length	0.4006	1.0861	0.9521	170
	height	length	0.5897	1.0975	0.9919	46
	length	width	2.6366	0.8766	0.9521	170
	height	width	1.5263	0.9994	0.9667	46
	length	height	1.6575	0.9038	0.9919	46
	width	height	0.7300	0.9672	0.9667	46
Quadrula pustulosa	width	length	0.7398	0.9658	0.9685	275
	height	length	0.9658	1.0007	0.9899	64
	length	width	1.5169	1.0028	0.9685	275
	height	width	1.4497	1.0070	0.9787	64
	length	height	1.0741	0.9892	0.9899	64
	width	height	0.7467	0.9719	0.9787	64
Quadrula quadrula	width	length	0.6841	0.9495	0.9687	43
	height	length	0.8678	0.9932	0.9932	18
	length	width	1.6687	1.0202	0.9687	43
	height	width	1.5423	0.9968	0.9916	18
	length	height	1.1831	1.0000	0.9932	18
	width	height	0.6680	0.9948	0.9916	18
Truncilla truncata	width	length	0.4154	1.0980	0.9542	563
	height	length	0.6609	1.0599	0.9676	203
	length	width	2.4966	0.8690	0.9542	563
	height	width	1.7162	0.9267	0.9715	198
	length	height	1.6248	0.9130	0.9676	203
	width	height	0.6142	1.0483	0.9715	198

Table G-6. Regression equation parameters of morphological measurements from mussels collected at Sylvan Slough site (RM 485.8), 1994-95. The relationship between morphological measurements were best described by a power regression equation ($y = ax^b$). Equation parameters are as follows : y = dependent variable; x = independent variable; a = y intercept; b = regression coefficient (slope); r^2 = coefficient of determination; and n = number of individuals plotted.

Example: Calculate the shell width and height of an *Amblema plicata* (Three ridge) with a shell length of 92.56 mm. ($y = ax^b$)
width =1.0138 × 92.56^0.8571 = **49.13 mm** ÷ 25.4 mm/inch = **1.93 inch**
height = 1.0400 × 92.56^0.9328 = **71.01 mm** ÷ 25.4 mm/inch = **2.80 inch**

Species	y	x	a	b	r^2	n
Amblema plicata	width	length	1.0138	0.8571	0.9421	111
	height	length	1.0400	0.9328	0.9855	55
	length	width	1.2507	1.0993	0.9421	111
	height	width	1.4189	0.9948	0.9594	55
	length	height	1.0178	1.0565	0.9855	55
	width	height	0.8228	0.9644	0.9594	55
Ellipsaria lineolata	width	length	0.1725	1.1977	0.8988	175
	height	length	0.5453	1.0892	0.9797	81
	length	width	5.5838	0.7505	0.8988	175
	height	width	3.5760	0.8149	0.9342	81
	length	height	1.8678	0.8994	0.9797	81
	width	height	0.2811	1.1463	0.9342	81
Megalonaias nervosa	width	length	0.4347	0.9771	0.9106	66
	height	length	0.7203	0.9953	0.9831	41
	length	width	3.3050	0.9319	0.9106	66
	height	width	2.6178	0.9034	0.9584	41
	length	height	1.4963	0.9877	0.9831	41
	width	height	0.4203	1.0609	0.9584	41
Obliquaria reflexa	width	length	0.4515	1.0558	0.9486	110
	height	length	0.7197	0.9953	0.9860	71
	length	width	2.4494	0.8985	0.9486	110
	height	width	1.6706	0.9639	0.9553	71
	length	height	1.4359	0.9497	0.9860	71
	width	height	0.6854	0.9911	0.9553	71
Quadrula pustulosa	width	length	0.6041	1.0213	0.9801	407
	height	length	0.8438	1.0388	0.9926	222
	length	width	1.7413	0.9596	0.9801	407
	height	width	1.5105	0.9950	0.9880	221
	length	height	1.2074	0.9555	0.9926	222
	width	height	0.6891	0.9930	0.9880	221
Quadrula quadrula	width	length	1.0972	0.8426	0.9420	48
	height	length	0.9918	0.9725	0.9818	38
	length	width	1.1248	1.1179	0.9420	48
	height	width	1.2563	1.0573	0.9795	38
	length	height	1.0825	1.0096	0.9818	38
	width	height	0.8673	0.9263	0.9795	38
Truncilla truncata	width	length	0.3922	1.1102	0.9739	234
	height	length	0.5451	1.1187	0.9891	109
	length	width	2.4700	0.8773	0.9394	234
	height	width	1.5716	0.9634	0.9877	109
	length	height	1.7696	0.8841	0.9891	109
	width	height	0.6492	1.0252	0.9877	109

Table G-7 : Formulas to calculate (a) live weight and (b) dry shell weight from shell length and height (mm) for commercial mussel species collected in Reach 15 of the Upper Mississippi River, 1994-95. The relationship between weight and shell size was best described by a power regression (y = ax^b). Equation parameters are as follows: y = dependent variable; x = independent variable; a = y-intercept; b = regression coefficient (slope); r^2 = coefficient of determination; and n = number of individuals plotted.

Example : Calculate the live weight and dry shell weight for five *Amblema plicata* having measured shell heights of : 75.10, 85.01, 72.52, 76.15, and 91.23. What is the present commercial value of these mussels ($0.86/lb dry shell)?

Calculations: y = ax^b

Live weight (g) = (0.0013×75.10^2.8266)+(0.0013×85.01^2.8266)+(0.0013×72.52^2.8266)+(0.0013×76.15^2.8266)+(0.0013×91.23^2.8266)
= 260.39 + 369.64 + 235.89 + 270.81 + 451.30
= 1588.03 g ÷ 454 g/pound = 3.50 pounds

Dry shell weight (g) = (0.0013×75.10^2.7444)+(0.0013×85.01^2.7444)+(0.0013×72.52^2.7444)+(0.0013×76.15^2.7444)+(0.0013×91.23^2.7444)
= 182.58 + 256.56 + 165.88 + 189.67 + 311.42
= 1106.10 g ÷ 454 g/pound = 2.44 pounds @ $0.86/pound = $2.10

(a) Live weight (g)

Species	y	x	a	b	r^2	n
Amblema plicata	Live wgt.	length	0.0015	2.6419	0.9814	167
	Live wgt.	height	0.0013	2.8266	0.9853	167
Megalonaias nervosa	Live wgt.	length	0.0002	3.0167	0.9776	98
	Live wgt.	height	0.0007	2.9424	0.9704	98
Quadrula metanevra	Live wgt.	length	0.0005	2.9200	0.9765	32
	Live wgt.	height	0.0001	3.4266	0.9543	32
Quadrula pustulosa	Live wgt.	length	0.0011	2.7847	0.9333	210
	Live wgt.	height	0.0015	2.7103	0.9441	210
Quadrula quadrula	Live wgt.	length	0.0012	2.7035	0.9508	57
	Live wgt.	height	0.0010	2.8381	0.9897	57

(b) Dry shell weight (g)

Species	y	x	a	b	r^2	n
Amblema plicata	Dry shell wgt.	length	0.0015	2.5620	0.9733	172
	Dry shell wgt.	height	0.0013	2.7444	0.9779	172
Megalonaias nervosa	Dry shell wgt.	length	0.0002	2.9057	0.9643	100
	Dry shell wgt.	height	0.0007	2.8437	0.9626	100
Quadrula metanevra	Dry shell wgt.	length	0.0005	2.8487	0.9574	32
	Dry shell wgt.	height	0.0001	3.3415	0.9348	32
Quadrula pustulosa	Dry shell wgt.	length	0.0014	2.6490	0.9551	204
	Dry shell wgt.	height	0.0016	2.6358	0.9619	204
Quadrula quadrula	Dry shell wgt.	length	0.0011	2.6574	0.9464	57
	Dry shell wgt.	height	0.0009	2.7893	0.9849	57

Table G-8 : Estimated abundance and weight of commercially sized (a) *Amblema plicata* (Three ridge) and *Megalonaias nervosa* (Washboard) at three Reach 15 study sites.

(a) *Amblema plicata* (Three ridge)

Site	n	Mean Height (mm)	Density (/m²)	Weight Live (g)	Weight Dry Shell (g)	Mussels/area hectare	Mussels/area acre	Live Weight (kg/hectare)	Live Weight (lbs/acre)	Dry Shell Weight (kg/hectare)	Dry Shell Weight (lbs/acre)
Sylvan Slough	8	72.36	0.24	234.42	164.87	2424	970	568.34	500.74	399.72	352.18
Case-IH	21	73.91	1.12	248.90	174.75	11314	4526	2816.02	2481.07	1977.10	1741.94
Illiniwek	27	73.78	0.63	247.66	173.91	6364	2546	1576.15	1388.68	1106.76	975.12

(b) *Megalonaias nervosa* (Washboard)

Site	n	Mean Height (mm)	Density (/m²)	Weight Live (g)	Weight Dry Shell (g)	Mussels/area hectare	Mussels/area acre	Live Weight (kg/hectare)	Live Weight (lbs/acre)	Dry Shell Weight (kg/hectare)	Dry Shell Weight (lbs/acre)
Sylvan Slough	5	107.12	0.17	657.34	414.42	1717	687	1128.85	994.58	711.68	627.03
Case-IH	1	106.72	0.06	650.14	410.03	606	242	394.06	347.19	248.52	218.96
Illiniwek	8	110.61	0.24	722.37	453.98	2424	970	1751.33	1543.02	1100.64	969.73

Example: Commercially sized *Amblema plicata* from Sylvan Slough.

Live Weight (g) = 0.0013 × Mean Height (72.36 mm)^2.8266 = 234.42 g
Dry Shell Weight (g) = 0.0013 × Mean Height (72.36 mm)^2.7444 = 164.87 g

Mussels/hectare = 10,101.78 m²/hectare × 0.24 mussels/m² = 2,424 mussels/hectare
Live Weight (kg/hectare) = 2,424 mussels/hectare × 234.42 g/mussel * 1kg/1000g = 568.34 kg/hectare
Dry Shell Weight (kg/hectare) = 2,424 mussels/hectare × 164.87 g/mussel * 1kg/1000g = 399.72 kg/hectare

Mussels/acre = 4040.71 m²/acre × 0.24 mussels/m² = 970 mussels/acre
Live Weight (lbs./acre) = 970 mussels/acre × 234.42 g/mussel * 1 lbs./454 g = 500.74 lbs./acre
Dry Shell Weight (lbs/acre) = 970 mussels/acre × 164.87 g/mussel × 1 lbs./454 g = 352.18 lbs/acre

Part II.

Average observed morphological shell measurements of commercial mussel species of various ages from Reach 15 of the Upper Mississippi River, 1987 and 1994-95.

Table G-9. Average observed morphological shell measurements of *Amblema plicata* (Threeridge) of various ages from Reach 15 of the Upper Mississippi River, collected in (a) 1994-95 and (b) 1987 quantitative surveys by the Illinois Natural History Survey.

(a) 1994-95		Average size at age					
		millimeters			inches		
Age (yrs.)	n	Length	Width	Height	Length	Width	Height
1	0	----	----	----	----	----	----
2	3	16.75	10.12	14.71	0.66	0.40	0.58
3	8	26.79	17.33	22.26	1.05	0.68	0.88
4	4	31.33	19.30	26.22	1.23	0.76	1.03
5	8	36.66	23.79	30.05	1.44	0.94	1.18
6	9	47.13	27.84	38.43	1.86	1.10	1.51
7	11	57.20	33.36	46.70	2.25	1.31	1.84
8	17	60.05	34.98	48.73	2.36	1.38	1.92
9	8	62.74	37.05	51.29	2.47	1.46	2.02
10	7	69.62	38.55	55.29	2.74	1.52	2.18
11	12	70.36	39.77	56.34	2.77	1.57	2.22
12	8	70.16	38.08	56.33	2.76	1.50	2.22
13	5	75.76	39.61	60.56	2.98	1.56	2.38
14	4	76.04	42.91	61.42	2.99	1.69	2.42
15	6	80.49	42.63	63.26	3.17	1.68	2.49
16	3	83.25	44.52	63.38	3.28	1.75	2.50
17	7	83.53	43.80	66.46	3.29	1.72	2.62
18	2	82.52	45.01	63.07	3.25	1.77	2.48
19	3	89.81	45.96	69.14	3.54	1.81	2.72
20	2	88.31	49.07	69.03	3.48	1.93	2.72
21	1	91.02	50.71	69.27	3.58	2.00	2.73
22	1	94.75	44.13	72.57	3.73	1.74	2.86
23	0	----	----	----	----	----	----
24	1	97.24	48.40	74.34	3.83	1.91	2.93
25	0	----	----	----	----	----	----
26	0	----	----	----	----	----	----
27	0	----	----	----	----	----	----
28	3	97.18	47.91	75.70	3.83	1.89	2.98
29	1	98.25	50.39	76.48	3.87	1.98	3.01
30	0	----	----	----	----	----	----
31	1	100.17	50.67	77.87	3.94	1.99	3.07
32	1	100.96	53.75	78.44	3.97	2.12	3.09
33	0	----	----	----	----	----	----
34	1	107.37	56.84	83.06	4.23	2.24	3.27
Total 137							

(b) 1987		Average size at age					
		millimeters			inches		
Age (yrs.)	n	Length	Width	Height	Length	Width	Height
1	1	14.76	10.18	12.81	0.58	0.40	0.50
2	7	20.06	12.53	17.37	0.79	0.49	0.68
3	11	27.47	16.79	23.16	1.08	0.66	0.91
4	17	34.28	20.43	28.47	1.35	0.80	1.12
5	29	44.40	25.56	36.47	1.75	1.01	1.44
6	42	48.41	27.58	39.57	1.91	1.09	1.56
7	22	53.53	30.24	43.35	2.11	1.19	1.71
8	15	56.70	31.88	45.55	2.23	1.26	1.79
9	11	60.44	33.77	48.25	2.38	1.33	1.90
10	9	67.11	37.15	53.03	2.64	1.46	2.09
11	8	66.27	36.71	52.74	2.61	1.45	2.08
12	8	70.86	38.97	55.99	2.79	1.53	2.20
13	11	68.25	37.69	54.18	2.69	1.48	2.13
14	11	76.74	41.84	60.42	3.02	1.65	2.38
15	9	73.54	40.28	57.77	2.90	1.59	2.27
16	11	81.24	44.12	63.97	3.20	1.74	2.52
17	16	77.99	42.49	61.60	3.07	1.67	2.43
18	20	79.61	43.32	62.88	3.13	1.71	2.48
19	25	79.77	43.41	63.00	3.14	1.71	2.48
20	13	83.21	45.03	65.32	3.28	1.77	2.57
21	13	85.67	46.31	67.32	3.37	1.82	2.65
22	17	83.78	45.35	65.86	3.30	1.79	2.59
23	9	83.00	45.00	65.37	3.27	1.77	2.57
24	18	84.11	45.45	66.01	3.31	1.79	2.60
25	7	83.47	45.23	65.71	3.29	1.78	2.59
26	7	86.52	46.72	67.93	3.41	1.84	2.67
27	3	83.56	45.27	65.78	3.29	1.78	2.59
28	3	85.43	46.19	67.14	3.36	1.82	2.64
29	1	91.76	49.29	71.77	3.61	1.94	2.83
30	0	----	----	----	----	----	----
31	1	99.81	53.20	77.61	3.93	2.09	3.06
32	1	102.08	54.29	79.25	4.02	2.14	3.12
33	0	----	----	----	----	----	----
34	1	104.27	55.35	80.83	4.11	2.18	3.18
Total 377							

Table G-10. Average observed morphological shell measurements of *Megalonaias nervosa* (Washboard) of various ages from Reach 15 of the Upper Mississippi River, collected in (a) 1994-95 and (b) 1987 quantitative surveys by the Illinois Natural History Survey.

(a) 1994-95		Average size at age					
		millimeters			inches		
Age (yrs.)	n	Length	Width	Height	Length	Width	Height
1	0	----	----	----	----	----	----
2	1	32.97	10.86	21.52	1.30	0.43	0.85
3	3	46.89	16.44	32.63	1.85	0.65	1.28
4	1	39.79	15.95	27.18	1.57	0.63	1.07
5	3	61.36	22.09	41.71	2.42	0.87	1.64
6	1	84.53	34.64	57.59	3.33	1.36	2.27
7	9	90.68	37.70	64.91	3.57	1.48	2.56
8	6	97.61	37.59	70.94	3.84	1.48	2.79
9	11	105.09	40.73	73.91	4.14	1.60	2.91
10	6	112.19	43.57	79.01	4.42	1.72	3.11
11	9	113.98	44.98	79.58	4.49	1.77	3.13
12	7	119.05	47.07	83.28	4.69	1.85	3.28
13	5	121.08	46.96	85.29	4.77	1.85	3.36
14	1	124.46	49.60	85.43	4.90	1.95	3.36
15	2	124.37	49.59	95.27	4.90	1.95	3.75
16	2	126.66	56.00	89.94	4.99	2.20	3.54
17	0	----	----	----	----	----	----
18	2	129.64	57.73	90.14	5.10	2.27	3.55
19	4	131.12	54.71	95.02	5.16	2.15	3.74
20	1	132.14	45.20	89.39	5.20	1.78	3.52
21	1	138.47	55.92	96.63	5.45	2.20	3.80
22	2	139.91	57.41	99.62	5.51	2.26	3.92
23	1	141.34	52.57	96.64	5.56	2.07	3.80
24	0	----	----	----	----	----	----
25	0	----	----	----	----	----	----
26	0	----	----	----	----	----	----
27	1	153.28	58.79	104.48	6.03	2.31	4.11
28	0	----	----	----	----	----	----
29	0	----	----	----	----	----	----
30	0	----	----	----	----	----	----
Total	79						

(b) 1987		Average size at age					
		millimeters			inches		
Age (yrs.)	n	Length	Width	Height	Length	Width	Height
1	0	----	----	----	----	----	----
2	23	34.47	13.79	24.31	1.36	0.54	0.96
3	58	45.99	18.30	32.47	1.81	0.72	1.28
4	5	57.12	22.63	40.37	2.25	0.89	1.59
5	14	67.36	26.61	47.51	2.65	1.05	1.87
6	5	70.30	27.86	49.68	2.77	1.10	1.96
7	1	92.56	36.27	65.26	3.64	1.43	2.57
8	2	88.67	34.78	62.53	3.49	1.37	2.46
9	1	94.69	37.09	66.75	3.73	1.46	2.63
10	0	----	----	----	----	----	----
11	0	----	----	----	----	----	----
12	4	109.63	42.80	77.23	4.32	1.68	3.04
13	0	----	----	----	----	----	----
14	1	123.80	48.19	87.16	4.87	1.90	3.43
15	1	121.95	47.48	85.86	4.80	1.87	3.38
16	3	126.86	49.35	89.31	4.99	1.94	3.52
17	1	130.15	50.60	91.61	5.12	1.99	3.61
18	0	----	----	----	----	----	----
19	2	126.26	49.76	90.00	4.97	1.96	3.54
20	3	121.77	48.11	86.87	4.79	1.89	3.42
21	2	130.71	51.54	93.35	5.15	2.03	3.68
22	2	141.50	55.74	101.17	5.57	2.19	3.98
23	1	131.23	52.26	94.56	5.17	2.06	3.72
24	0	----	----	----	----	----	----
25	0	----	----	----	----	----	----
26	2	141.13	54.77	99.30	5.56	2.16	3.91
27	0	----	----	----	----	----	----
28	0	----	----	----	----	----	----
29	0	----	----	----	----	----	----
30	0	----	----	----	----	----	----
Total	131						

Table G-11. Average observed morphological shell measurements of *Quadrula quadrula* (Mapleleaf) of various ages from Reach 15 of the Upper Mississippi River, collected in (a) 1994-95 and (b) 1987 quantitative surveys by the Illinois Natural History Survey.

(a) 1994-95		Average size at age					
		millimeters			inches		
Age (yrs.)	n	Length	Width	Height	Length	Width	Height
1	0	----	----	----	----	----	----
2	0	----	----	----	----	----	----
3	1	20.78	13.53	18.03	0.82	0.53	0.71
4	1	35.24	22.93	30.23	1.39	0.90	1.19
5	5	39.45	25.44	37.18	1.55	1.00	1.46
6	0	----	----	----	----	----	----
7	1	40.92	23.21	34.63	1.61	0.91	1.36
8	2	44.72	34.91	50.24	1.76	1.37	1.98
9	2	57.14	35.42	51.45	2.25	1.39	2.03
10	1	58.21	34.33	50.70	2.29	1.35	2.00
11	2	60.65	36.09	54.46	2.39	1.42	2.14
12	3	61.28	37.77	54.30	2.41	1.49	2.14
13	0	----	----	----	----	----	----
14	1	67.52	33.80	56.58	2.66	1.33	2.23
15	2	69.38	40.89	60.56	2.73	1.61	2.38
16	1	69.80	37.04	57.54	2.75	1.46	2.27
17	2	74.70	45.06	64.57	2.94	1.77	2.54
18	1	72.21	40.53	60.07	2.84	1.60	2.36
19	1	72.50	38.86	65.13	2.85	1.53	2.56
20	1	76.44	45.02	63.81	3.01	1.77	2.51
21	2	75.90	39.36	64.01	2.99	1.55	2.52
22	0	----	----	----	----	----	----
23	2	84.73	41.84	67.37	3.34	1.65	2.65
24	1	79.09	42.49	64.94	3.11	1.67	2.56
25	0	----	----	----	----	----	----
26	0	----	----	----	----	----	----
27	0	----	----	----	----	----	----
28	1	87.83	49.67	73.94	3.46	1.96	2.91
29	0	----	----	----	----	----	----
30	0	----	----	----	----	----	----
Total	33						

(b) 1987		Average size at age					
		millimeters			inches		
Age (yrs.)	n	Length	Width	Height	Length	Width	Height
1	0	----	----	----	----	----	----
2	1	20.62	12.11	17.53	0.81	0.48	0.69
3	3	29.44	17.63	25.51	1.16	0.69	1.00
4	0	----	----	----	----	----	----
5	5	41.80	23.68	35.37	1.65	0.93	1.39
6	14	48.38	27.31	41.06	1.90	1.08	1.62
7	8	48.71	27.38	41.17	1.92	1.08	1.62
8	3	52.10	29.63	44.83	2.05	1.17	1.76
9	3	55.71	31.44	47.91	2.19	1.24	1.89
10	1	55.74	31.12	47.07	2.19	1.23	1.85
11	2	63.20	35.07	53.32	2.49	1.38	2.10
12	2	64.50	36.18	55.76	2.54	1.42	2.20
13	2	71.80	40.20	63.31	2.83	1.58	2.49
14	1	71.60	40.11	63.14	2.82	1.58	2.49
15	0	----	----	----	----	----	----
16	1	70.46	38.88	59.41	2.77	1.53	2.34
17	0	----	----	----	----	----	----
18	0	----	----	----	----	----	----
19	1	71.62	39.49	60.38	2.82	1.55	2.38
20	1	71.35	39.35	60.15	2.81	1.55	2.37
21	3	76.58	42.18	65.49	3.01	1.66	2.58
22	1	71.19	39.26	60.02	2.80	1.55	2.36
23	0	----	----	----	----	----	----
24	0	----	----	----	----	----	----
25	0	----	----	----	----	----	----
26	0	----	----	----	----	----	----
27	1	71.91	39.64	60.62	2.83	1.56	2.39
28	0	----	----	----	----	----	----
29	1	80.01	44.04	70.34	3.15	1.73	2.77
30	0	----	----	----	----	----	----
Total	54						

Table G-12. Average observed morphological shell measurements of *Quadrula pustulosa* (Pimpleback) of various ages from Reach 15 of the Upper Mississippi River, collected in (a) 1994-95 and (b) 1987 quantitative surveys by the Illinois Natural History Survey.

(a) 1994-95		Average size at age					
		millimeters			inches		
Age (yrs.)	n	Length	Width	Height	Length	Width	Height
1	1	7.93	4.18	6.48	0.31	0.16	0.26
2	1	12.23	7.38	10.75	0.48	0.29	0.42
3	3	21.14	14.26	20.79	0.83	0.56	0.82
4	14	27.58	18.69	27.13	1.09	0.74	1.07
5	24	32.91	22.25	32.29	1.30	0.88	1.27
6	19	33.50	22.39	33.27	1.32	0.88	1.31
7	24	41.27	26.84	39.76	1.62	1.06	1.57
8	18	44.23	29.01	42.63	1.74	1.14	1.68
9	13	48.68	31.28	47.32	1.92	1.23	1.86
10	4	48.73	32.29	46.61	1.92	1.27	1.84
11	7	52.50	32.90	50.43	2.07	1.30	1.99
12	4	54.27	34.13	53.38	2.14	1.34	2.10
13	4	55.00	34.96	53.49	2.17	1.38	2.11
14	2	60.26	38.75	58.36	2.37	1.53	2.30
15	5	57.13	36.22	55.54	2.25	1.43	2.19
16	0	----	----	----	----	----	----
17	1	61.19	36.65	58.90	2.41	1.44	2.32
18	1	61.91	38.70	58.52	2.44	1.52	2.30
19	1	66.37	37.90	58.00	2.61	1.49	2.28
20	0	----	----	----	----	----	----
21	0	----	----	----	----	----	----
22	0	----	----	----	----	----	----
23	0	----	----	----	----	----	----
24	0	----	----	----	----	----	----
25	0	----	----	----	----	----	----
26	0	----	----	----	----	----	----
27	0	----	----	----	----	----	----
28	0	----	----	----	----	----	----
29	0	----	----	----	----	----	----
30	0	----	----	----	----	----	----
Total	146						

(b) 1987		Average size at age					
		millimeters			inches		
Age (yrs.)	n	Length	Width	Height	Length	Width	Height
1	6	13.66	9.24	13.21	0.54	0.36	0.52
2	11	16.94	11.28	16.31	0.67	0.44	0.64
3	24	22.92	15.10	22.08	0.90	0.59	0.87
4	74	29.08	19.08	28.10	1.14	0.75	1.11
5	57	34.18	22.37	33.08	1.35	0.88	1.30
6	118	40.81	26.61	39.57	1.61	1.05	1.56
7	250	42.19	27.50	40.93	1.66	1.08	1.61
8	51	46.70	30.56	45.62	1.84	1.20	1.80
9	30	49.22	32.24	48.20	1.94	1.27	1.90
10	18	51.98	34.00	50.90	2.05	1.34	2.00
11	7	53.19	34.74	52.06	2.09	1.37	2.05
12	22	54.26	35.54	53.25	2.14	1.40	2.10
13	9	57.60	37.49	56.29	2.27	1.48	2.22
14	6	57.15	37.13	55.75	2.25	1.46	2.20
15	4	58.89	38.19	57.40	2.32	1.50	2.26
16	5	62.27	40.73	61.23	2.45	1.60	2.41
17	8	60.53	39.18	58.96	2.38	1.54	2.32
18	4	63.76	42.09	63.21	2.51	1.66	2.49
19	4	63.76	42.09	63.21	2.51	1.66	2.49
20	4	62.96	40.42	60.98	2.48	1.59	2.40
21	0	----	----	----	----	----	----
22	1	63.63	42.00	63.08	2.51	1.65	2.48
23	0	----	----	----	----	----	----
24	0	----	----	----	----	----	----
25	0	----	----	----	----	----	----
26	1	70.26	44.94	68.05	2.77	1.77	2.68
27	0	----	----	----	----	----	----
28	0	----	----	----	----	----	----
29	0	----	----	----	----	----	----
30	0	----	----	----	----	----	----
Total	714						

Table G-13. Average observed morphological shell measurements of *Quadrula metanevra* (Monkeyface) of various ages from Reach 15 of the Upper Mississippi River, collected in 1987 quantitative survey by the Illinois Natural History Survey.

1987		Average size at age					
		millimeters			inches		
Age (yrs.)	n	Length	Width	Height	Length	Width	Height
1	1	13.94	9.85	16.02	0.55	0.39	0.63
2	1	22.23	11.93	23.44	0.88	0.47	0.92
3	4	29.55	16.78	29.54	1.16	0.66	1.16
4	5	41.27	23.27	38.82	1.62	0.92	1.53
5	3	45.55	26.31	42.09	1.79	1.04	1.66
6	3	43.54	24.26	40.59	1.71	0.96	1.60
7	2	40.26	22.35	38.05	1.59	0.88	1.50
8	5	56.27	31.81	50.04	2.22	1.25	1.97
9	3	53.36	30.08	47.92	2.10	1.18	1.89
10	7	56.03	31.67	49.86	2.21	1.25	1.96
11	5	59.39	33.68	52.29	2.34	1.33	2.06
12	5	60.83	34.54	53.34	2.39	1.36	2.10
13	7	63.48	35.99	55.22	2.50	1.42	2.17
14	1	62.56	35.58	54.58	2.46	1.40	2.15
15	2	68.48	39.14	58.76	2.70	1.54	2.31
16	4	64.79	36.92	56.15	2.55	1.45	2.21
17	3	67.45	38.52	58.03	2.66	1.52	2.28
18	2	68.07	38.90	58.47	2.68	1.53	2.30
19	1	70.51	40.37	60.18	2.78	1.59	2.37
20	3	70.15	40.15	59.92	2.76	1.58	2.36
21	0	----	----	----	----	----	----
22	3	73.81	42.37	62.47	2.91	1.67	2.46
23	1	75.95	43.66	63.94	2.99	1.72	2.52
24	3	73.66	42.28	62.36	2.90	1.66	2.46
25	0	----	----	----	----	----	----
26	1	76.15	43.78	64.08	3.00	1.72	2.52
27	1	77.67	44.71	65.12	3.06	1.76	2.56
28	1	78.33	45.11	65.58	3.08	1.78	2.58
29	0	----	----	----	----	----	----
30	1	78.89	45.45	65.96	3.11	1.79	2.60
Total	78						

Part III.

Calculated morphological shell measurements of commercial mussel species of various ages from Reach 15 of the Upper Mississippi River.

Table G-14. Calculated morphological shell measurements of *Amblema plicata* (Threeridge) of various ages from Reach 15 of the Upper Mississippi River, (a) 1994-95 and (b) 1987. Formulas used to calculate size at age are listed in Table G-4.

(a) 1994-95	Average size at age					
Age	millimeters			inches		
(yrs.)	Length	Width	Height	Length	Width	Height
1	9.04	6.49	8.37	0.36	0.26	0.33
2	17.80	11.62	15.42	0.70	0.46	0.61
3	25.88	16.28	21.88	1.02	0.64	0.86
4	33.33	20.49	27.79	1.31	0.81	1.09
5	40.16	24.28	33.17	1.58	0.96	1.31
6	46.41	27.66	38.05	1.83	1.09	1.50
7	52.10	30.67	42.46	2.05	1.21	1.67
8	57.27	33.32	46.42	2.25	1.31	1.83
9	61.95	35.64	49.96	2.44	1.40	1.97
10	66.17	37.66	53.12	2.60	1.48	2.09
11	69.95	39.40	55.91	2.75	1.55	2.20
12	73.33	40.88	58.36	2.89	1.61	2.30
13	76.34	42.13	60.51	3.01	1.66	2.38
14	79.00	43.16	62.38	3.11	1.70	2.46
15	81.35	44.01	64.00	3.20	1.73	2.52
16	83.42	44.70	65.39	3.28	1.76	2.57
17	85.24	45.25	66.59	3.36	1.78	2.62
18	86.83	45.69	67.61	3.42	1.80	2.66
19	88.24	46.04	68.50	3.47	1.81	2.70
20	89.48	46.32	69.27	3.52	1.82	2.73
21	90.58	46.56	69.95	3.57	1.83	2.75
22	91.59	46.78	70.57	3.61	1.84	2.78
23	92.52	47.00	71.16	3.64	1.85	2.80
24	93.41	47.26	71.75	3.68	1.86	2.82
25	94.29	47.57	72.36	3.71	1.87	2.85
26	95.18	47.95	73.03	3.75	1.89	2.88
27	96.12	48.44	73.77	3.78	1.91	2.90
28	97.15	49.05	74.61	3.82	1.93	2.94
29	98.27	49.81	75.59	3.87	1.96	2.98
30	99.54	50.75	76.74	3.92	2.00	3.02
31	100.98	51.88	78.07	3.98	2.04	3.07
32	102.61	53.23	79.62	4.04	2.10	3.13
33	104.47	54.82	81.41	4.11	2.16	3.21
34	106.59	56.69	83.47	4.20	2.23	3.29

(b) 1987	Average size at age					
Age	millimeters			inches		
(yrs.)	Length	Width	Height	Length	Width	Height
1	12.63	9.08	11.78	0.50	0.36	0.46
2	21.17	13.49	18.30	0.83	0.53	0.72
3	28.93	17.49	24.23	1.14	0.69	0.95
4	35.96	21.11	29.59	1.42	0.83	1.16
5	42.28	24.37	34.42	1.66	0.96	1.35
6	47.95	27.28	38.74	1.89	1.07	1.53
7	52.99	29.87	42.59	2.09	1.18	1.68
8	57.47	32.17	46.00	2.26	1.27	1.81
9	61.40	34.19	49.00	2.42	1.35	1.93
10	64.85	35.95	51.63	2.55	1.42	2.03
11	67.84	37.47	53.91	2.67	1.48	2.12
12	70.42	38.78	55.87	2.77	1.53	2.20
13	72.63	39.90	57.55	2.86	1.57	2.27
14	74.51	40.85	58.97	2.93	1.61	2.32
15	76.11	41.65	60.18	3.00	1.64	2.37
16	77.45	42.32	61.19	3.05	1.67	2.41
17	78.60	42.88	62.04	3.09	1.69	2.44
18	79.57	43.35	62.77	3.13	1.71	2.47
19	80.43	43.76	63.40	3.17	1.72	2.50
20	81.20	44.13	63.97	3.20	1.74	2.52
21	81.93	44.47	64.50	3.23	1.75	2.54
22	82.66	44.81	65.03	3.25	1.76	2.56
23	83.43	45.17	65.59	3.28	1.78	2.58
24	84.28	45.57	66.20	3.32	1.79	2.61
25	85.26	46.04	66.91	3.36	1.81	2.63
26	86.40	46.59	67.74	3.40	1.83	2.67
27	87.75	47.24	68.73	3.45	1.86	2.71
28	89.34	48.02	69.90	3.52	1.89	2.75
29	91.23	48.94	71.29	3.59	1.93	2.81
30	93.44	50.04	72.92	3.68	1.97	2.87
31	96.02	51.32	74.84	3.78	2.02	2.95
32	99.01	52.82	77.06	3.90	2.08	3.03
33	102.46	54.55	79.62	4.03	2.15	3.13
34	106.40	56.53	82.56	4.19	2.23	3.25

Table G-15. Calculated morphological shell measurements of *Megalonaias nervosa* (Washboard) of various ages from Reach 15 of the Upper Mississippi River, (a) 1994-95 and (b) 1987. Formulas used to calculate size at age are listed in Table G-4.

(a) 1994-95	Average size at age					
Age	millimeters			inches		
(yrs.)	Length	Width	Height	Length	Width	Height
1	9.80	1.84	5.04	0.39	0.07	0.20
2	26.94	8.88	17.43	1.06	0.35	0.69
3	42.29	15.23	28.56	1.66	0.60	1.12
4	55.96	20.93	38.49	2.20	0.82	1.52
5	68.07	26.01	47.30	2.68	1.02	1.86
6	78.72	30.51	55.06	3.10	1.20	2.17
7	88.02	34.46	61.85	3.47	1.36	2.44
8	96.07	37.92	67.74	3.78	1.49	2.67
9	102.98	40.91	72.79	4.05	1.61	2.87
10	108.86	43.47	77.09	4.29	1.71	3.04
11	113.82	45.64	80.71	4.48	1.80	3.18
12	117.95	47.46	83.71	4.64	1.87	3.30
13	121.37	48.96	86.18	4.78	1.93	3.39
14	124.19	50.19	88.18	4.89	1.98	3.47
15	126.50	51.18	89.78	4.98	2.01	3.53
16	128.43	51.97	91.06	5.06	2.05	3.59
17	130.06	52.59	92.10	5.12	2.07	3.63
18	131.52	53.09	92.95	5.18	2.09	3.66
19	132.91	53.50	93.71	5.23	2.11	3.69
20	134.33	53.86	94.43	5.29	2.12	3.72
21	135.89	54.20	95.19	5.35	2.13	3.75
22	137.70	54.57	96.07	5.42	2.15	3.78
23	139.87	55.01	97.13	5.51	2.17	3.82
24	142.50	55.55	98.45	5.61	2.19	3.88
25	145.69	56.22	100.11	5.74	2.21	3.94
26	149.56	57.07	102.16	5.89	2.25	4.02
27	154.21	58.14	104.70	6.07	2.29	4.12
28	159.75	59.45	107.78	6.29	2.34	4.24
29	166.29	61.06	111.48	6.55	2.40	4.39
30	173.93	63.00	115.88	6.85	2.48	4.56

(b) 1987	Average size at age					
Age	millimeters			inches		
(yrs.)	Length	Width	Height	Length	Width	Height
1	19.94	8.59	14.79	0.78	0.34	0.58
2	33.53	13.69	24.07	1.32	0.58	0.95
3	45.88	18.35	32.53	1.81	0.72	1.28
4	57.06	22.57	40.23	2.25	0.89	1.58
5	67.15	26.40	47.21	2.64	1.04	1.86
6	76.19	29.85	53.50	3.00	1.18	2.11
7	84.26	32.94	59.14	3.32	1.30	2.33
8	91.43	35.70	64.19	3.60	1.41	2.53
9	97.75	38.15	68.67	3.85	1.50	2.70
10	103.30	40.32	72.64	4.07	1.59	2.86
11	108.14	42.22	76.12	4.26	1.66	3.00
12	112.34	43.88	79.18	4.42	1.73	3.12
13	115.96	45.33	81.84	4.57	1.78	3.22
14	119.06	46.58	84.15	4.69	1.83	3.31
15	121.72	47.66	86.14	4.79	1.88	3.39
16	123.99	48.59	87.87	4.88	1.91	3.46
17	125.95	49.40	89.37	4.96	1.94	3.52
18	127.66	50.11	90.69	5.03	1.97	3.57
19	129.18	50.74	91.86	5.09	2.00	3.62
20	130.58	51.32	92.92	5.14	2.02	3.66
21	131.93	51.86	93.93	5.19	2.04	3.70
22	133.28	52.39	94.91	5.25	2.06	3.74
23	134.72	52.94	95.92	5.30	2.08	3.78
24	136.30	53.52	96.99	5.37	2.11	3.82
25	138.08	54.17	98.16	5.44	2.13	3.86
26	140.14	54.90	99.48	5.52	2.16	3.92
27	142.53	55.73	100.99	5.61	2.19	3.98
28	145.33	56.70	102.73	5.72	2.23	4.04
29	148.60	57.82	104.74	5.85	2.28	4.12
30	152.41	59.11	107.06	6.00	2.33	4.21

Table G-16. Calculated morphological shell measurements of *Quadrula quadrula* (Mapleleaf) of various ages from Reach 15 of the Upper Mississippi River, (a) 1994-95 and (b) 1987. Formulas used to calculate size at age are listed in Table G-4.

(a) 1994-95	Average size at age					
Age	millimeters			inches		
(yrs.)	Length	Width	Height	Length	Width	Height
1	10.76	6.31	7.00	0.42	0.25	0.28
2	17.95	11.44	14.65	0.71	0.45	0.58
3	24.54	16.00	21.53	0.97	0.63	0.85
4	30.57	20.02	27.67	1.20	0.79	1.09
5	36.07	23.55	33.11	1.42	0.93	1.30
6	41.08	26.61	37.92	1.62	1.05	1.49
7	45.61	29.25	42.12	1.80	1.15	1.66
8	49.71	31.50	45.77	1.96	1.24	1.80
9	53.41	33.39	48.92	2.10	1.31	1.93
10	56.73	34.96	51.61	2.23	1.38	2.03
11	59.71	36.25	53.88	2.35	1.43	2.12
12	62.37	37.28	55.79	2.46	1.47	2.20
13	64.76	38.11	57.38	2.55	1.50	2.26
14	66.89	38.76	58.69	2.63	1.53	2.31
15	68.81	39.26	59.77	2.71	1.55	2.35
16	70.54	39.67	60.67	2.78	1.56	2.39
17	72.11	40.00	61.43	2.84	1.57	2.42
18	73.55	40.30	62.10	2.90	1.59	2.45
19	74.91	40.59	62.73	2.95	1.60	2.47
20	76.20	40.93	63.36	3.00	1.61	2.49
21	77.45	41.34	64.04	3.05	1.63	2.52
22	78.71	41.86	64.81	3.10	1.65	2.55
23	80.00	42.52	65.72	3.15	1.67	2.59
24	81.34	43.36	66.81	3.20	1.71	2.63
25	82.78	44.42	68.14	3.26	1.75	2.68
26	84.35	45.73	69.75	3.32	1.80	2.75
27	86.06	47.33	71.68	3.39	1.86	2.82
28	87.97	49.25	73.99	3.46	1.94	2.91
29	90.09	51.53	76.70	3.55	2.03	3.02
30	92.45	54.21	79.89	3.64	2.13	3.15

(b) 1987	Average size at age					
Age	millimeters			inches		
(yrs.)	Length	Width	Height	Length	Width	Height
1	13.65	8.51	10.81	0.54	0.34	0.43
2	21.42	12.76	17.78	0.84	0.50	0.70
3	28.46	16.61	24.07	1.12	0.65	0.95
4	34.81	20.07	29.71	1.37	0.79	1.17
5	40.51	23.16	34.74	1.59	0.91	1.37
6	45.59	25.92	39.20	1.79	1.02	1.54
7	50.09	28.35	43.11	1.97	1.12	1.70
8	54.05	30.48	46.53	2.13	1.20	1.83
9	57.51	32.33	49.48	2.26	1.27	1.95
10	60.49	33.92	52.01	2.38	1.34	2.05
11	63.05	35.27	54.14	2.48	1.39	2.13
12	65.21	36.40	55.92	2.57	1.43	2.20
13	67.01	37.34	57.38	2.64	1.47	2.26
14	68.49	38.10	58.56	2.70	1.50	2.31
15	69.69	38.70	59.49	2.74	1.52	2.34
16	70.65	39.18	60.21	2.78	1.54	2.37
17	71.39	39.54	60.76	2.81	1.56	2.39
18	71.96	39.80	61.17	2.83	1.57	2.41
19	72.39	40.00	61.48	2.85	1.57	2.42
20	72.73	40.14	61.73	2.86	1.58	2.43
21	73.00	40.26	61.95	2.87	1.58	2.44
22	73.25	40.36	62.18	2.88	1.59	2.45
23	73.51	40.48	62.46	2.89	1.59	2.46
24	73.82	40.64	62.82	2.91	1.60	2.47
25	74.22	40.84	63.30	2.92	1.61	2.49
26	74.74	41.12	63.93	2.94	1.62	2.52
27	75.42	41.50	64.76	2.97	1.63	2.55
28	76.29	42.00	65.82	3.00	1.65	2.59
29	77.40	42.63	67.13	3.05	1.68	2.64
30	78.78	43.42	68.76	3.10	1.71	2.71

Table G-17. Calculated morphological shell measurements of *Quadrula pustulosa* (Pimpleback) of various ages from Reach 15 of the Upper Mississippi River, (a) 1994-95 and (b) 1987. Formulas used to calculate size at age are listed in Table G-4.

(a) 1994-95	Average size at age					
Age	millimeters			inches		
(yrs.)	Length	Width	Height	Length	Width	Height
1	6.71	3.85	6.06	0.26	0.15	0.24
2	14.18	8.99	13.21	0.56	0.35	0.52
3	20.83	13.56	19.67	0.82	0.53	0.77
4	26.75	17.58	25.49	1.05	0.69	1.00
5	31.97	21.10	30.70	1.26	0.83	1.21
6	36.56	24.14	35.33	1.44	0.95	1.39
7	40.58	26.76	39.41	1.60	1.05	1.55
8	44.08	28.99	42.99	1.74	1.14	1.69
9	47.12	30.86	46.09	1.86	1.22	1.81
10	49.76	32.41	48.76	1.96	1.28	1.92
11	52.06	33.69	51.02	2.05	1.33	2.01
12	54.06	34.72	52.91	2.13	1.37	2.08
13	55.84	35.54	54.46	2.20	1.40	2.14
14	57.44	36.20	55.72	2.26	1.43	2.19
15	58.93	36.72	56.70	2.32	1.45	2.23
16	60.36	37.15	57.46	2.38	1.46	2.26
17	61.79	37.53	58.02	2.43	1.48	2.28
18	63.27	37.88	58.42	2.49	1.49	2.30
19	64.87	38.26	58.68	2.55	1.51	2.31
20	66.64	38.69	58.86	2.62	1.52	2.32
21	68.64	39.22	58.97	2.70	1.54	2.32
22	70.93	39.88	59.06	2.79	1.57	2.33
23	73.55	40.70	59.16	2.90	1.60	2.33
24	76.58	41.74	59.31	3.02	1.64	2.34
25	80.07	43.01	59.54	3.15	1.69	2.34
26	84.07	44.57	59.87	3.31	1.75	2.36
27	88.64	46.44	60.36	3.49	1.83	2.38
28	93.85	48.67	61.03	3.69	1.92	2.40
29	99.74	51.30	61.92	3.93	2.02	2.44
30	106.37	54.35	63.06	4.19	2.14	2.48

(b) 1987	Average size at age					
Age	millimeters			inches		
(yrs.)	Length	Width	Height	Length	Width	Height
1	11.68	7.99	11.25	0.46	0.31	0.44
2	18.33	12.22	17.69	0.72	0.48	0.70
3	24.34	16.04	23.52	0.96	0.63	0.93
4	29.74	19.50	28.78	1.17	0.77	1.13
5	34.57	22.59	33.50	1.36	0.89	1.32
6	38.86	25.36	37.71	1.53	1.00	1.48
7	42.65	27.81	41.45	1.68	1.09	1.63
8	45.98	29.98	44.75	1.81	1.18	1.76
9	48.89	31.88	47.65	1.92	1.25	1.88
10	51.41	33.53	50.18	2.02	1.32	1.98
11	53.58	34.97	52.37	2.11	1.38	2.06
12	55.44	36.20	54.25	2.18	1.43	2.14
13	57.03	37.25	55.87	2.25	1.47	2.20
14	58.38	38.15	57.25	2.30	1.50	2.25
15	59.53	38.92	58.43	2.34	1.53	2.30
16	60.52	39.57	59.45	2.38	1.56	2.34
17	61.39	40.14	60.32	2.42	1.58	2.37
18	62.17	40.63	61.10	2.45	1.60	2.41
19	62.89	41.08	61.81	2.48	1.62	2.43
20	63.61	41.51	62.49	2.50	1.63	2.46
21	64.35	41.93	63.17	2.53	1.65	2.49
22	65.16	42.38	63.88	2.57	1.67	2.51
23	66.06	42.87	64.66	2.60	1.69	2.55
24	67.10	43.42	65.54	2.64	1.71	2.58
25	68.32	44.06	66.56	2.69	1.73	2.62
26	69.75	44.80	67.75	2.75	1.76	2.67
27	71.43	45.68	69.14	2.81	1.80	2.72
28	73.39	46.71	70.77	2.89	1.84	2.79
29	75.68	47.92	72.66	2.98	1.89	2.86
30	78.33	49.32	74.87	3.08	1.94	2.95

Table G-18. Calculated morphological shell measurements of *Quadrula metanevra* (Monkeyface) of various ages from Reach 15 of the Upper Mississippi River, (a) 1994-95 and (b) 1987. Formulas used to calculate size at age are listed in Table G-4.

(b) 1987	Average size at age					
Age	millimeters			inches		
(yrs.)	Length	Width	Height	Length	Width	Height
1	17.57	7.99	11.25	0.69	0.31	0.44
2	23.90	12.22	17.69	0.94	0.48	0.70
3	29.67	16.04	23.52	1.17	0.63	0.93
4	34.92	19.50	28.78	1.37	0.77	1.13
5	39.68	22.59	33.50	1.56	0.89	1.32
6	43.96	25.36	37.71	1.73	1.00	1.48
7	47.81	27.81	41.45	1.88	1.09	1.63
8	51.25	29.98	44.75	2.02	1.18	1.76
9	54.30	31.88	47.65	2.14	1.25	1.88
10	57.01	33.53	50.18	2.24	1.32	1.98
11	59.39	34.97	52.37	2.34	1.38	2.06
12	61.47	36.20	54.25	2.42	1.43	2.14
13	63.28	37.25	55.87	2.49	1.47	2.20
14	64.86	38.15	57.25	2.55	1.50	2.25
15	66.23	38.92	58.43	2.61	1.53	2.30
16	67.41	39.57	59.45	2.65	1.56	2.34
17	68.45	40.14	60.32	2.69	1.58	2.37
18	69.36	40.63	61.10	2.73	1.60	2.41
19	70.17	41.08	61.81	2.76	1.62	2.43
20	70.92	41.51	62.49	2.79	1.63	2.46
21	71.63	41.93	63.17	2.82	1.65	2.49
22	72.33	42.38	63.88	2.85	1.67	2.51
23	73.05	42.87	64.66	2.88	1.69	2.55
24	73.82	43.42	65.54	2.91	1.71	2.58
25	74.67	44.06	66.56	2.94	1.73	2.62
26	75.62	44.80	67.75	2.98	1.76	2.67
27	76.70	45.68	69.14	3.02	1.80	2.72
28	77.95	46.71	70.77	3.07	1.84	2.79
29	79.39	47.92	72.66	3.13	1.89	2.86
30	81.05	49.32	74.87	3.19	1.94	2.95

Part IV.

Growth curves for commercial mussel species from Reach 15 of the Upper Mississippi River, 1987 and 1994-95.

Figure G-1. Growth curves based on the average observed size at age (Table G-5) of *Amblema plicata* collected from Reach 15 of the Upper Mississippi River in (a) 1994-95 and (b) 1987. All growth curves were best described by a polynomial regression formula (Table G-4). Coefficient of determination (r^2) values for each growth curve are listed. Minimum commercial shell height (Illinois) and average age at sexual maturity (Table G-2) are also shown.

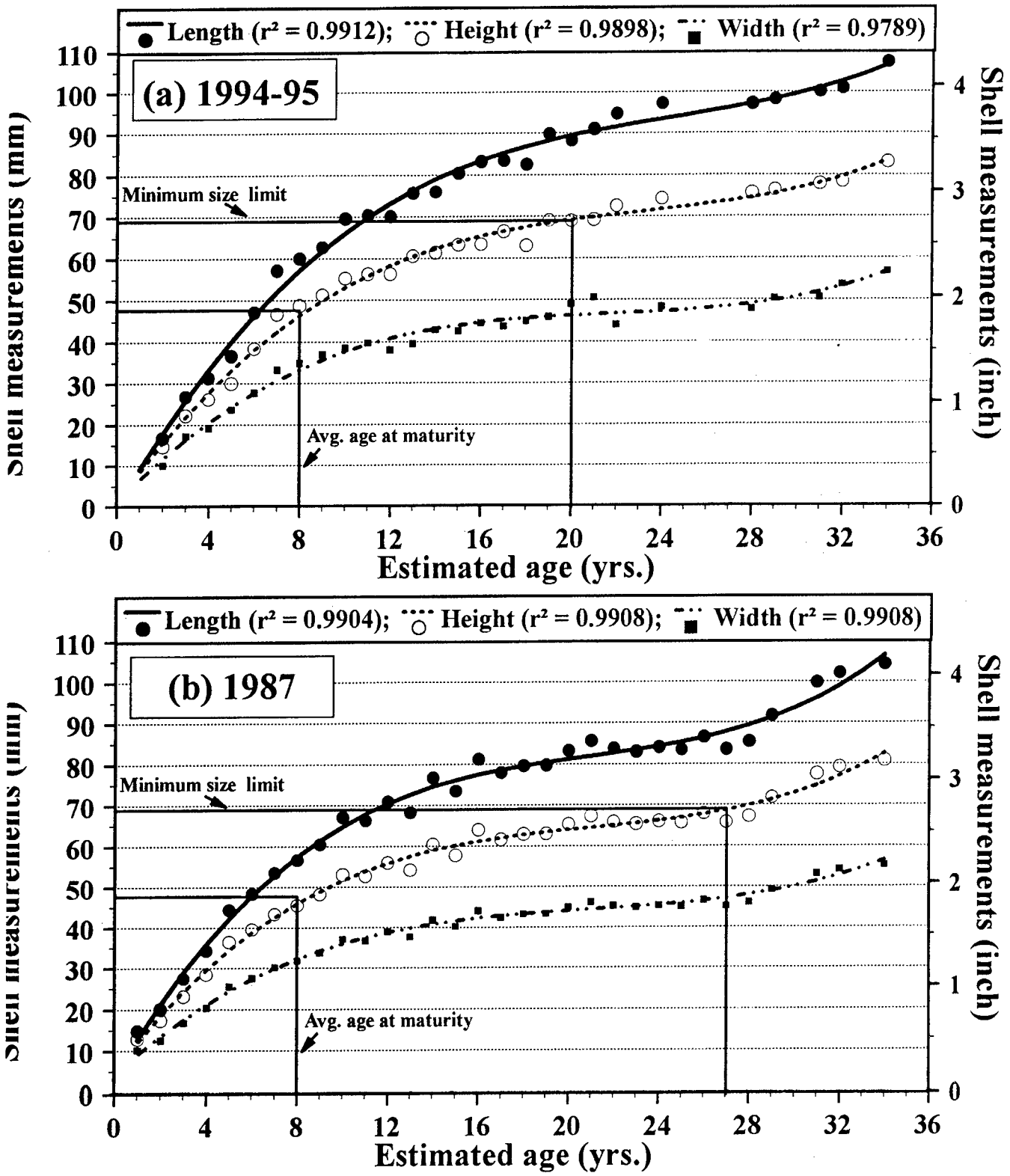
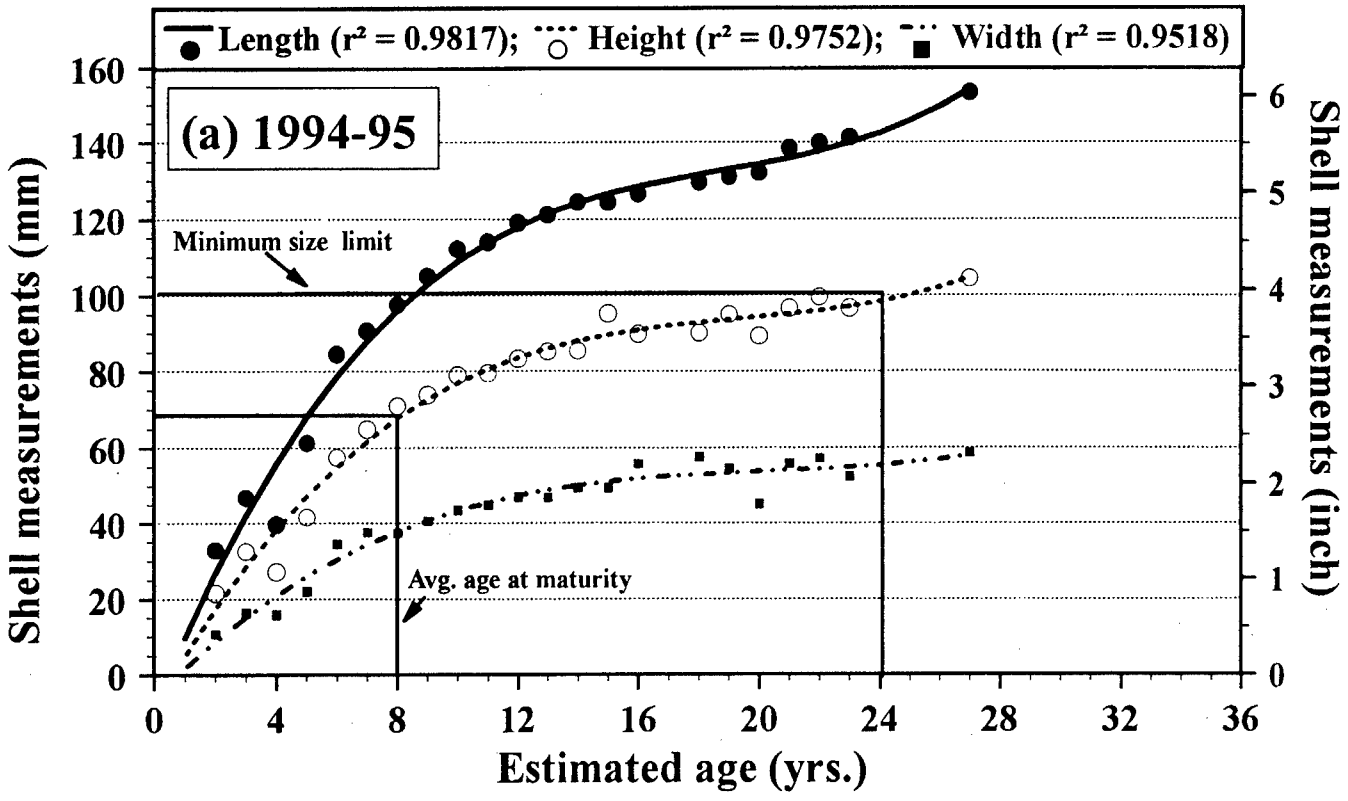


Figure G-2. Growth curves based on the average observed size at age (Table G-6) of *Megalonaias nervosa* collected from Reach 15 of the Upper Mississippi River in (a) 1994-95 and (b) 1987. All growth curves were best described by a polynomial regression formula (Table G-4). Coefficient of determination (r^2) values for each growth curve are listed. Minimum commercial shell height (Illinois) and average age at sexual maturity (Table G-2) are also shown.



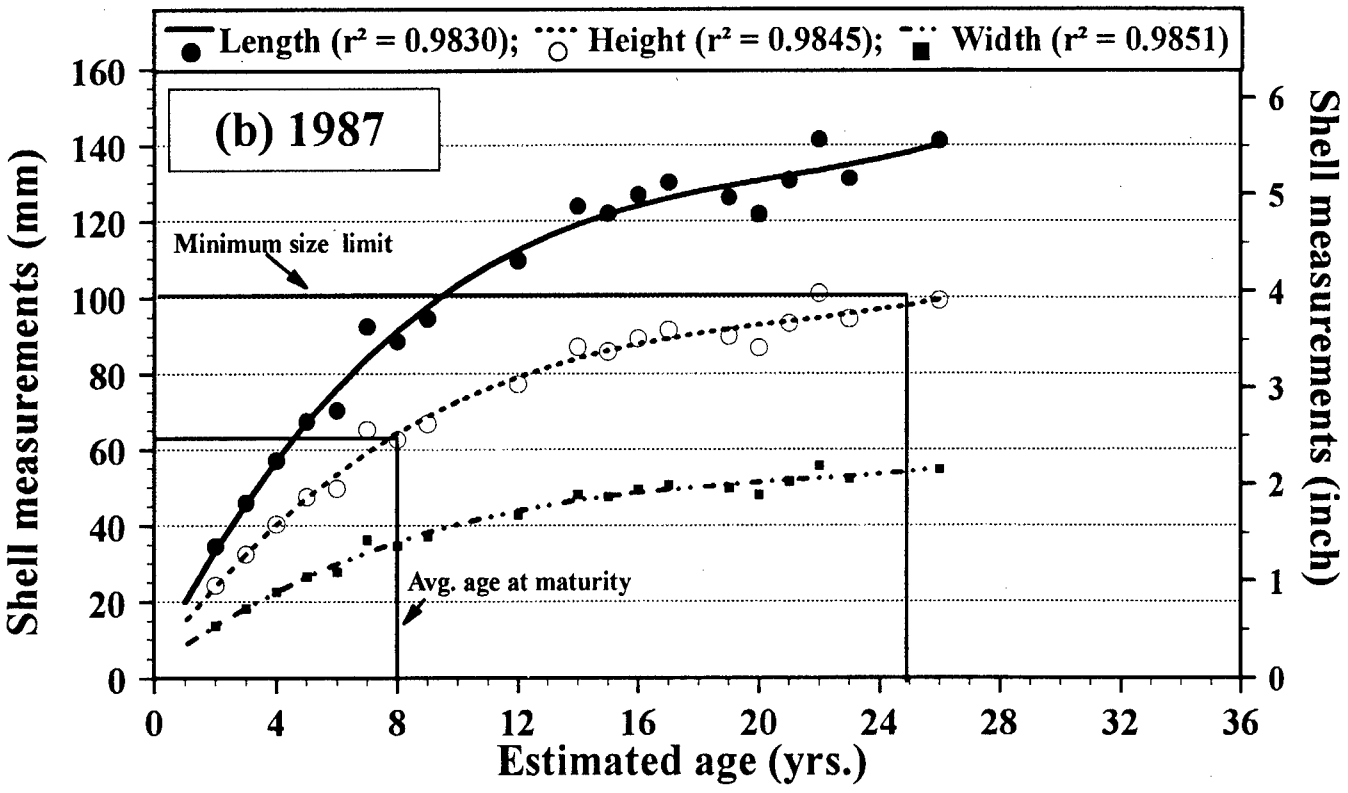


Figure G-3. Growth curves based on the average observed size at age (Table G-7) of *Quadrula quadrula* collected from Reach 15 of the Upper Mississippi River in (a) 1994-95 and (b) 1987. All growth curves were best described by a polynomial regression formula (Table G-4). Coefficient of determination (r^2) values for each growth curve are listed. Minimum commercial shell height (Illinois) and average age at sexual maturity (Table G-2) are also shown.

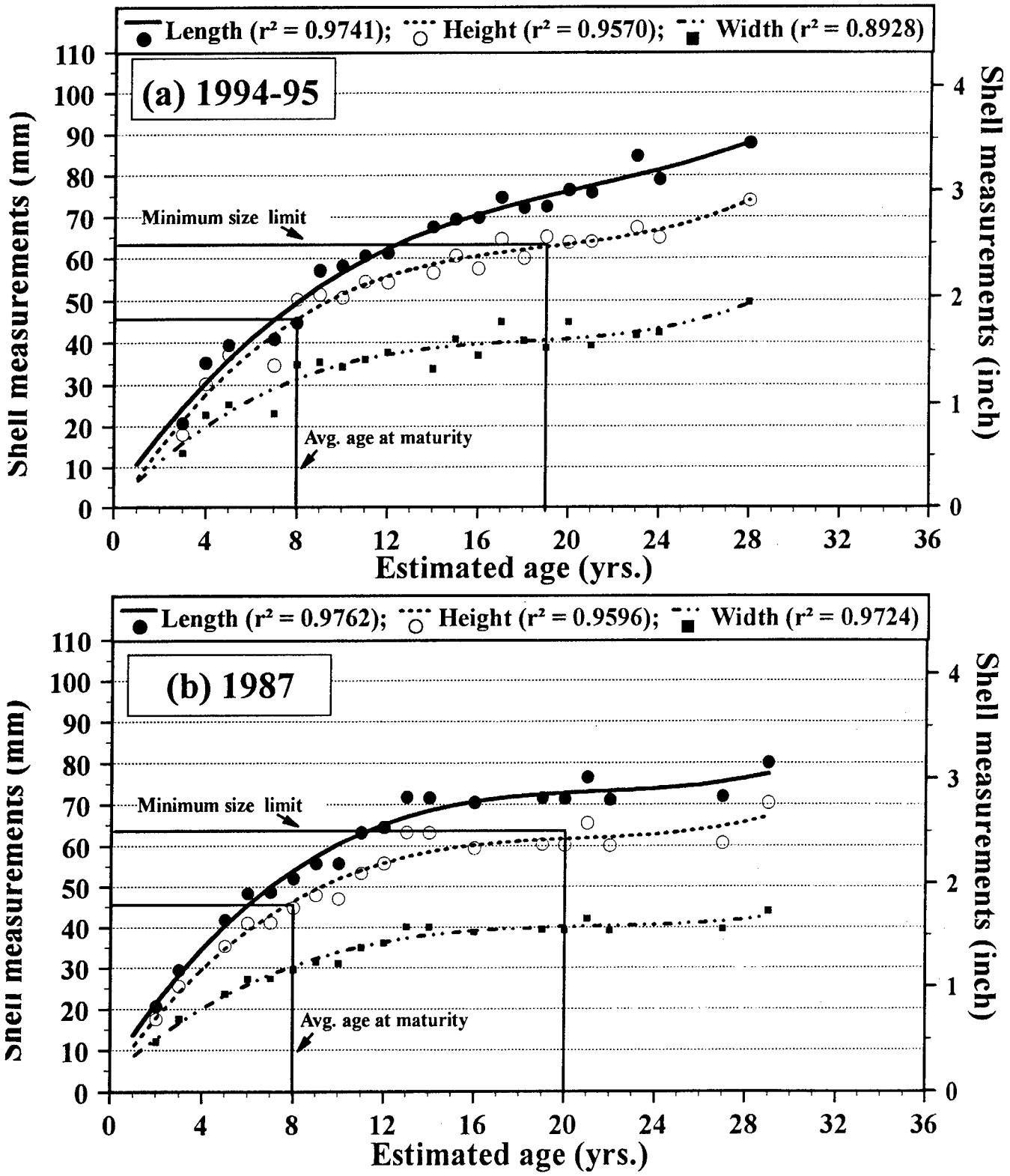


Figure G-4. Growth curves based on the average observed size at age (Table G-8) of *Quadrula pustulosa* collected from Reach 15 of the Upper Mississippi River in (a) 1994-95 and (b) 1987. All growth curves were best described by a polynomial regression formula (Table G-4). Coefficient of determination (r^2) values for each growth curve are listed. Minimum commercial shell height (Illinois) and average age at sexual maturity (Table G-2) are also shown.

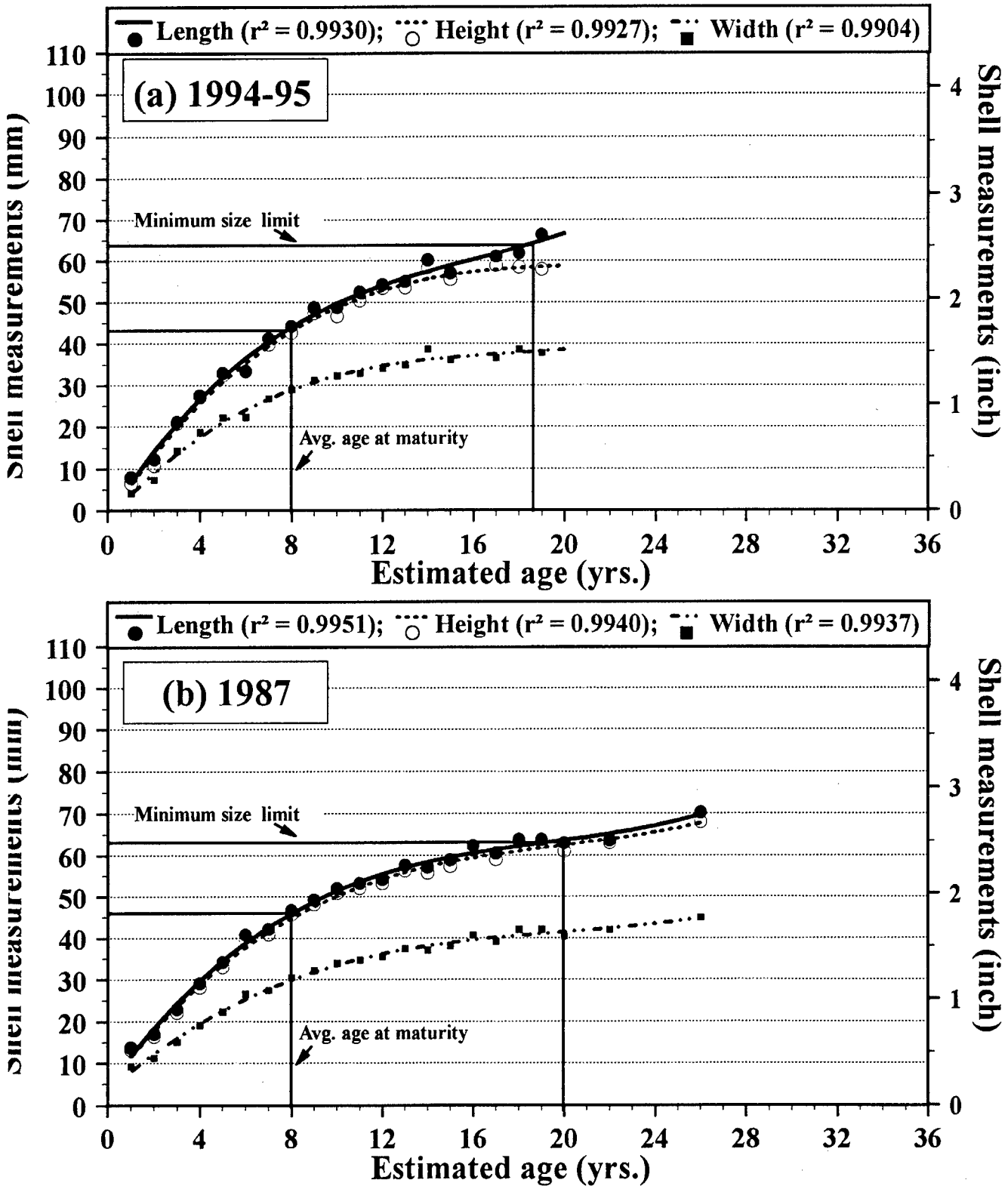
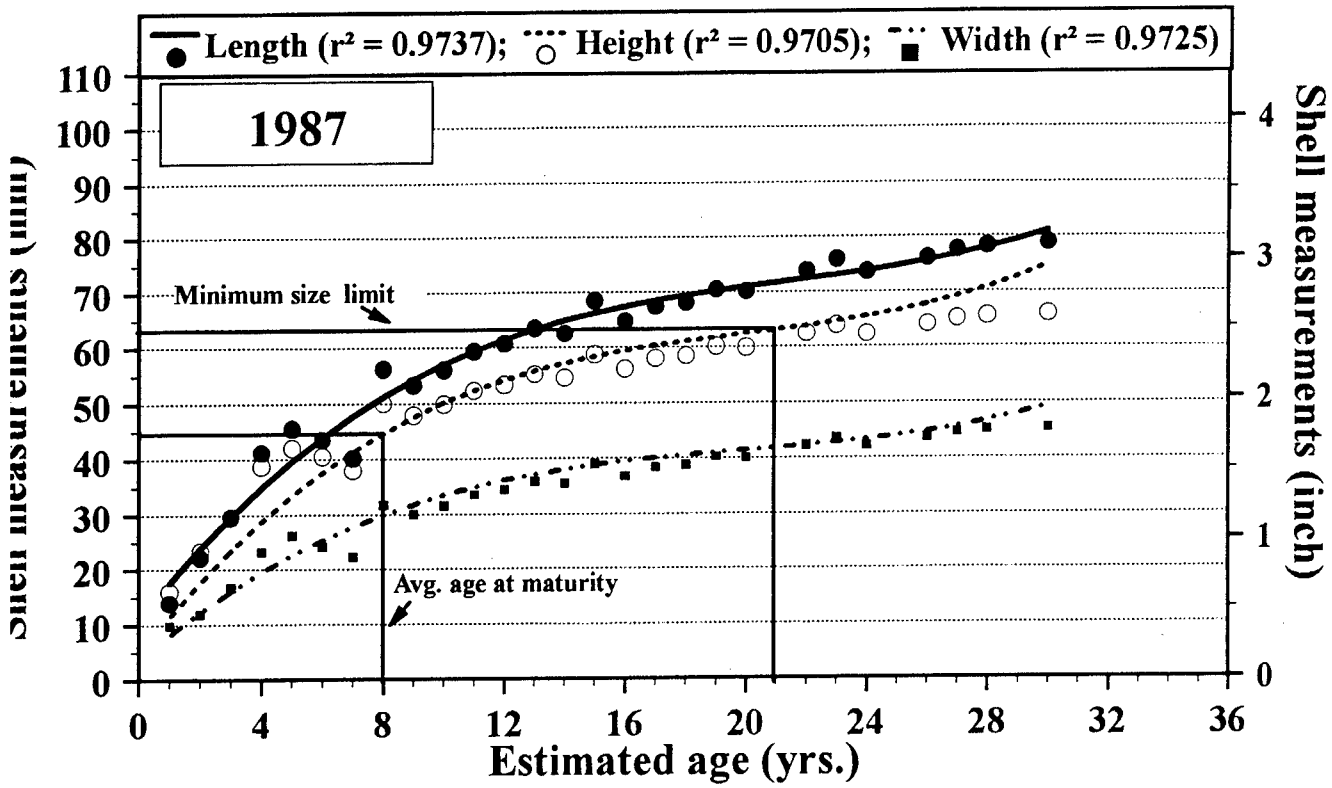


Figure G-5. Growth curves based on the average observed size at age (Table G-9) of *Quadrula metanevra* collected from Reach 15 of the Upper Mississippi River in 1987. All growth curves were best described by a polynomial regression formula (Table G-4). Coefficient of determination (r^2) values for each growth curve are listed. Minimum commercial shell height (Illinois) and average age at sexual maturity (Table G-2) are also shown.



Appendix H

Zebra Mussels (*Dreissena polymorpha*)

Reach 15 of the Upper Mississippi River

Appendix H

Zebra Mussels (*Dreissena polymorpha*)

Reach 15 of the Upper Mississippi River

Table H-1. Summary of quantitative sampling for zebra mussels at three sites in Reach 15 of the Upper Mississippi River, 1994-95.

	Quantitative Samples		Zebra mussel density (#/m²)		
Site / Date	**No.**	**Size (m²)**	**Mean**	**Std.Dev.**	**Range**
Sylvan Slough (RM 485.8)					
22 July 1994	72	0.25	0.6	1.4	0 - 4
12 July 1995	12	0.625	426.0	263.3	56 - 992
Case-IH (RM 488.5)					
20 July 1994	50	0.25	1.2	2.9	0 - 12
15 August 1994	22	0.25	34.2	33.8	0 - 128
Illiniwek (RM 492.4)					
22 July 1994	40	0.25	1.7	2.7	0 - 8
17 August 1994	22	0.25	36.7	24.5	0 - 88
11 July 1995	12	0.625	2518.7	730.5	1344 - 3728

Figure H-1. Length frequency histograms of zebra mussels collected at Illiniwek site (RM 492.4) in Reach 15 of the Upper Mississippi River from July 1994 through September 1995. Data used to generate these histograms is presented in Table H-2.

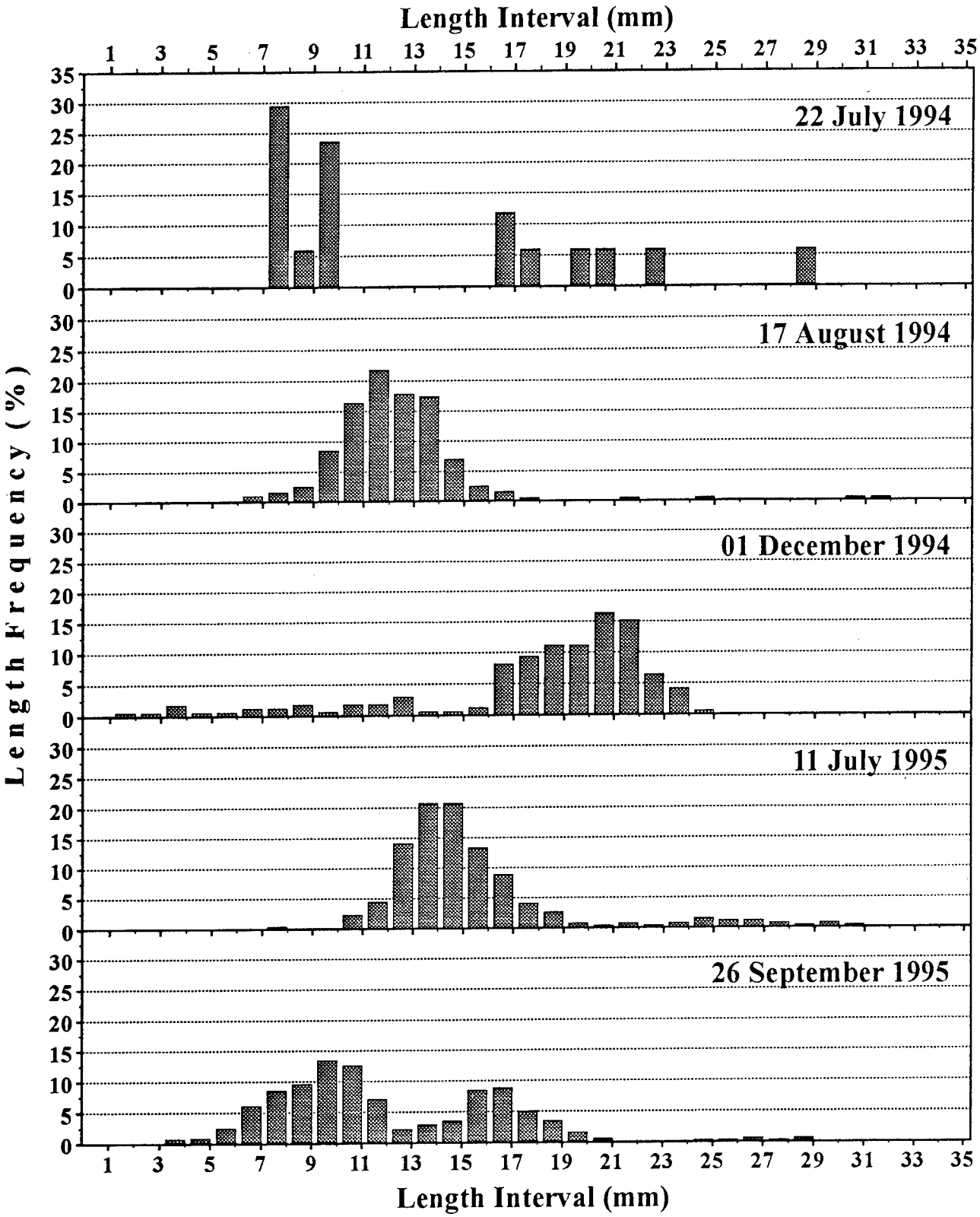


Table H-2. Population size structure of zebra mussels collected at Illiniwek study site (RM 492.4) in Reach 15 of the Upper Mississippi River between July 1994 and September 1995.

Length Interval (mm)	No. of zebra mussels / length interval				
	(7/22/94)	(8/17/94)	(12/01/95)	(7/10/95)	(9/26/95)
1	0	0	0	0	0
2	0	0	1	0	0
3	0	0	1	0	0
4	0	0	3	0	5
5	0	0	1	0	6
6	0	0	1	0	17
7	0	2	2	0	41
8	5	3	2	1	58
9	1	5	3	0	65
10	4	17	1	0	91
11	0	33	3	6	85
12	0	44	3	12	48
13	0	36	5	38	15
14	0	35	1	56	20
15	0	14	1	56	24
16	0	5	2	36	57
17	2	3	14	24	60
18	1	1	16	11	34
19	0	0	19	7	24
20	1	0	19	2	11
21	1	0	28	1	4
22	0	1	26	2	0
23	1	0	11	1	0
24	0	0	7	2	1
25	0	1	1	4	2
26	0	0	0	3	2
27	0	0	0	3	4
28	0	0	0	2	2
29	1	0	0	1	4
30	0	0	0	2	0
31	0	1	0	1	0
32	0	1	0	0	0
33	0	0	0	0	0
34	0	0	0	0	0
35	0	0	0	0	0
Totals	**17**	**202**	**171**	**271**	**680**

Length Interval (mm)	% of zebra mussels / length interval				
	(7/22/94)	(8/17/94)	(12/01/95)	(7/10/95)	(9/26/95)
1	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.58	0.00	0.00
3	0.00	0.00	0.58	0.00	0.00
4	0.00	0.00	1.75	0.00	0.74
5	0.00	0.00	0.58	0.00	0.88
6	0.00	0.00	0.58	0.00	2.50
7	0.00	0.99	1.17	0.00	6.03
8	29.41	1.49	1.17	0.37	8.53
9	5.88	2.48	1.75	0.00	9.56
10	23.53	8.42	0.58	0.00	13.38
11	0.00	16.34	1.75	2.21	12.50
12	0.00	21.78	1.75	4.43	7.06
13	0.00	17.82	2.92	14.02	2.21
14	0.00	17.33	0.58	20.66	2.94
15	0.00	6.93	0.58	20.66	3.53
16	0.00	2.48	1.17	13.28	8.38
17	11.76	1.49	8.19	8.86	8.82
18	5.88	0.50	9.36	4.06	5.00
19	0.00	0.00	11.11	2.58	3.53
20	5.88	0.00	11.11	0.74	1.62
21	5.88	0.00	16.37	0.37	0.59
22	0.00	0.50	15.20	0.74	0.00
23	5.88	0.00	6.43	0.37	0.00
24	0.00	0.00	4.09	0.74	0.15
25	0.00	0.50	0.58	1.48	0.29
26	0.00	0.00	0.00	1.11	0.29
27	0.00	0.00	0.00	1.11	0.59
28	0.00	0.00	0.00	0.74	0.29
29	5.88	0.00	0.00	0.37	0.59
30	0.00	0.00	0.00	0.74	0.00
31	0.00	0.50	0.00	0.37	0.00
32	0.00	0.50	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00
Totals	**100**	**100**	**100**	**100**	**100**

Figure H-2. Zebra mussel infestation of native unionids at two sites in Reach 15 of the Upper Mississippi River from July 1994 through September 1995. (a) % Infestation refers to the number of unionids with one or more attached zebra mussels, (b) Degree of Infestation refers to the number of attached zebra mussels on each unionid.

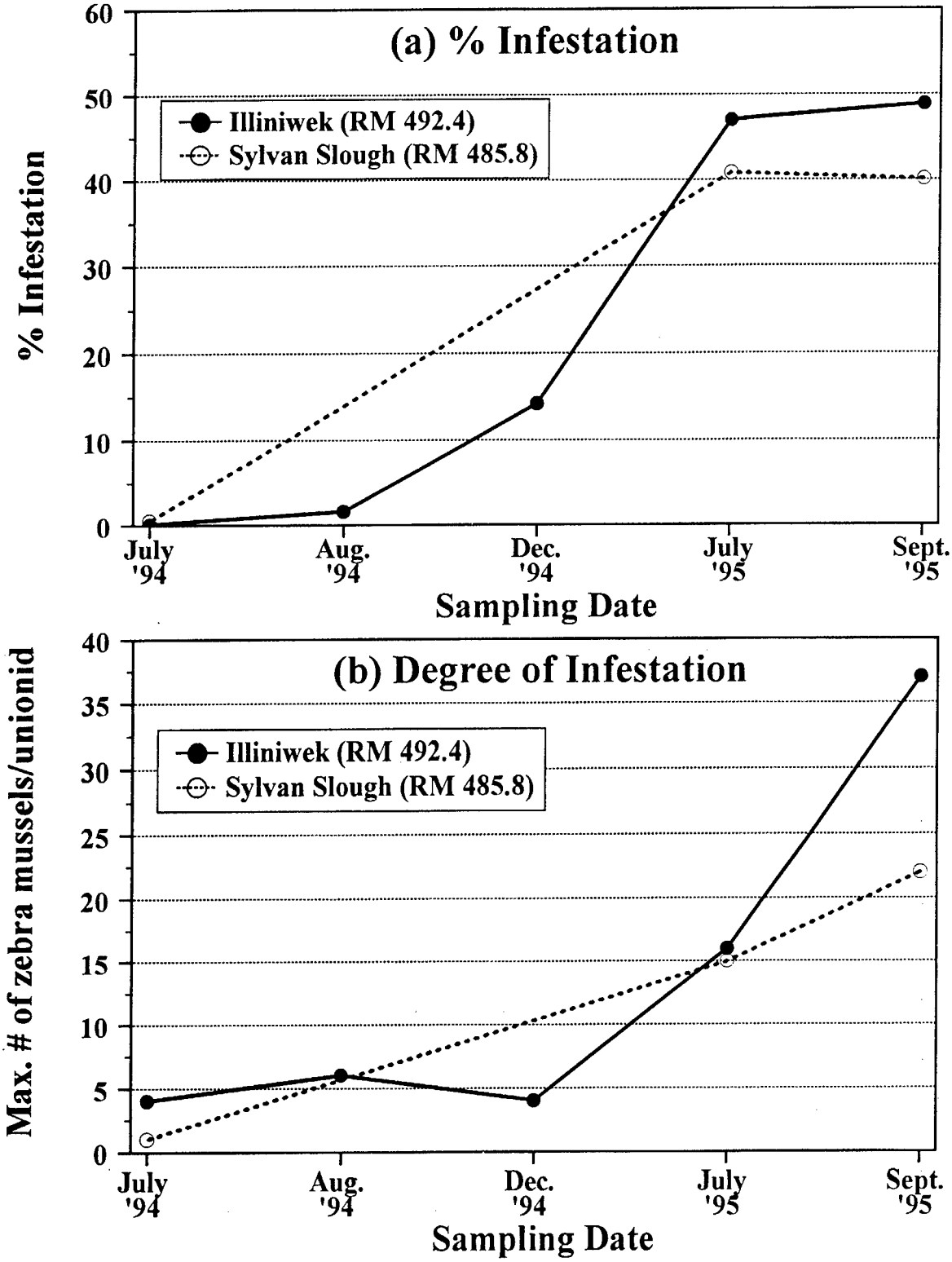


Table H-3. Zebra mussel infestation of native mussel species at the Sylvan Slough site (RM 485.8) in Reach 15 of the Upper Mississippi River on three sample dates between July 1994 and September 1995.

Species	Unionids processed			% Infestation			Degree of Infestation (no. of zebra mussels/unionid)					
							July '94		July '95		Sept. '95	
	July '94	July '95	Sept. '95	July '94	July '95	Sept. '95	avg.	max	avg.	max	avg.	max
1. *Actinonaias ligamentina*	2	1	0	0.0	0.0	0.0	0.00	0	0.00	0	0.00	0
2. *Amblema plicata*	57	32	17	1.75	78.1	52.9	0.02	1	2.62	15	1.32	5
3. *Arcidens confragosus*	2	0	0	0.0	0.0	0.0	0.00	0	0.00	0	0.00	0
4. *Ellipsaria lineolata*	128	60	30	0.78	43.3	43.3	0.01	1	0.75	5	1.27	9
5. *Fusconaia flava*	1	1	1	0.0	0.0	100.0	0.00	0	0.00	0	2.00	2
6. *Lampsilis cardium*	4	3	1	0.0	0.0	100.0	0.00	0	0.00	0	0.00	12
7. *Lampsilis higginsi*	2	1	0	0.0	0.0	0.0	0.00	0	0.00	0	0.00	0
8. *Leptodea fragilis*	35	15	5	0.0	13.3	20.0	0.00	0	0.53	6	0.20	1
9. *Ligumia recta*	6	1	4	0.0	0.0	75.0	0.00	0	0.00	0	3.50	12
10. *Megalonaias nervosa*	58	6	2	1.72	66.7	50.0	0.02	1	2.76	4	4.50	9
11. *Obliquaria reflexa*	73	35	21	0.0	68.6	28.6	0.00	0	1.64	6	0.57	3
12. *Obovaria olivaria*	1	0	0	0.0	0.0	0.0	0.00	0	0.00	0	0.00	0
13. *Plethobasus cyphyus*	6	3	1	0.0	66.7	0.0	0.00	0	4.33	10	0.00	0
14. *Potamilus alatus*	4	0	0	0.0	0.0	0.0	0.00	0	0.00	0	0.00	0
15. *Pyganodon grandis*	2	1	0	0.0	100.0	0.0	0.00	0	1.00	1	0.00	0
16. *Quadrula metanevra*	110	12	20	0.91	58.3	50.0	0.01	1	1.75	4	2.70	13
17. *Quadrula nodulata*	5	3	1	0.0	33.3	0.0	0.00	0	3.33	10	0.00	0
18. *Quadrula pustulosa*	251	135	83	0.40	41.5	43.4	0.00	1	0.79	8	1.32	22
19. *Quadrula quadrula*	23	28	9	0.0	82.1	44.4	0.00	0	3.04	11	1.67	5
20. *Strophitus undulatus*	0	1	0	0.0	100.0	0.0	0.00	0	1.00	1	0.00	0
21. *Truncilla donaciformis*	42	83	16	0.0	1.2	6.3	0.00	0	0.01	1	0.05	1
22. *Truncilla truncata*	137	92	55	0.0	39.1	38.2	0.00	0	0.90	6	1.07	0
23. *Utterbackia imbecillis*	2	4	1	0.0	0.0	0.0	0.00	0	0.00	0	0.00	0
Totals	**951**	**517**	**267**	**0.5**	**40.8**	**40.1**	**0.01**	**1**	**1.03**	**15**	**1.29**	**22**
Species	**22**	**20**	**16**									

Table H-4. Zebra mussel infestation of native mussel species at the Illiniwek site (RM 492.4) in Reach 15 of the Upper Mississippi River on five sample dates between July 1994 and September 1995.

Species	Unionids processed					% Infestation					Degree of Infestation (no. of zebra mussels/unionid)									
	July '94	Aug. '94	Dec. '94	July '95	Sept. '95	July '94	Aug. '94	Dec. '94	July '95	Sept. '95	July '94		Aug. '94		Dec. '94		July '95		Sept. '95	
											avg.	max	avg.	max	avg.	max	avg.	max	avg.	max
1. *Actinonaias ligamentina*	0	0	1	3	0	0.0	0.0	0.0	100.0	0.0	0.00	0	0.00	0	0.00	0	1.67	3	0.00	0
2. *Amblema plicata*	137	60	40	53	37	0.0	0.1	25.0	69.8	64.9	0.00	0	0.20	6	0.33	3	2.13	15	5.00	23
3. *Arcidens confragosus*	2	1	0	2	0	0.0	0.0	0.0	100.0	0.0	0.00	0	0.00	0	0.00	0	6.00	7	0.00	0
4. *Cumberlandia monodonta*	1	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
5. *Ellipsaria lineolata*	452	184	132	197	169	0.0	0.0	15.2	47.7	50.9	0.00	0	0.10	4	0.15	1	1.07	12	2.06	21
6. *Fusconaia flava*	5	5	2	3	2	0.0	0.0	0.0	66.7	50.0	0.00	0	0.00	0	0.00	0	2.67	5	1.00	2
7. *Lampsilis cardium*	4	5	5	6	3	0.0	0.0	0.0	33.3	66.7	0.00	0	0.00	0	0.00	0	0.67	3	1.33	2
8. *Lampsilis higginsi*	1	1	0	1	1	0.0	0.0	0.0	0.0	100.0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	5
9. *Lasmigona complanata*	4	0	1	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
10. *Leptodea fragilis*	32	24	5	34	20	0.0	0.0	0.0	17.6	0.0	0.00	0	0.00	0	0.00	0	0.30	4	0.00	0
11. *Ligumia recta*	3	0	3	3	0	0.0	0.0	33.3	0.0	0.0	0.00	0	0.00	0	0.67	2	0.00	0	0.00	0
12. *Megalonaias nervosa*	34	17	9	17	6	0.0	0.0	22.2	52.9	83.3	0.00	0	0.00	0	0.33	2	1.76	11	6.50	13
13. *Obliquaria reflexa*	130	72	24	36	31	0.0	0.0	8.3	63.9	54.8	0.00	0	0.00	0	0.08	1	1.51	10	1.77	12
14. *Obovaria olivaria*	1	0	0	2	1	0.0	0.0	0.0	0.0	0.0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
15. *Potamilus alatus*	5	2	1	1	1	0.0	0.0	0.0	0.0	0.0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
16. *Potamilus ohiensis*	0	1	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
17. *Pyganodon grandis*	2	3	1	9	1	0.0	0.0	0.0	88.9	100.0	0.00	0	0.00	0	0.00	0	7.33	15	0.00	24
18. *Quadrula metanevra*	5	3	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
19. *Quadrula nodulata*	0	0	0	1	1	0.0	0.0	0.0	0.0	100.0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1
20. *Quadrula pustulosa*	226	84	63	87	43	0.0	0.0	22.2	49.4	53.5	0.00	0	0.00	0	0.27	4	1.25	12	2.79	37
21. *Quadrula quadrula*	11	6	9	14	6	0.0	0.0	22.2	71.4	100.0	0.00	0	0.00	0	0.22	1	4.83	15	2.83	6
22. *Strophitus undulatus*	1	0	2	1	3	0.0	0.0	0.0	100.0	100.0	0.00	0	0.00	0	0.00	0	0.00	3	6.33	12
23. *Truncilla donaciformis*	8	4	1	12	5	0.0	0.0	0.0	0.0	20.0	0.00	0	0.00	0	0.00	0	0.00	0	0.60	3
24. *Truncilla truncata*	452	213	115	166	199	0.2	0.0	7.0	43.4	45.2	0.00	4	0.00	0	0.10	2	0.92	16	2.00	18
25. *Utterbackia imbecillis*	0	0	1	9	5	0.0	0.0	0.0	0.0	0.0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Totals	**1516**	**685**	**415**	**657**	**534**	**0.1**	**1.6**	**14.2**	**47.0**	**48.9**	**0.00**	**4**	**0.04**	**6**	**0.17**	**4**	**1.28**	**16**	**2.31**	**37**
Species	**21**	**17**	**18**	**21**	**18**															

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12a. DISTRIBUTION/AVAILABILITY STATEMENT

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12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

Unionid mussels were collected by quadrat sampling at three mussel beds in Reach 15 of the Upper Mississippi River (UMR) between July 1994 and September 1995. A total of 7,107 unionids were collected representing 26 species, including the federally endangered *Lampsilis higginsi*, state endangered *Plethobasus cyphyus* and *Cumberlandia monodonta*, and state threatened *Ellipsaria lineolata*. Mean densities at our study sites ranged from 53.4 to 118.3 mussels/m^2. Comparisons with data collected at these same sites in the early 1980s revealed significant declines in unionid abundance, sporadic recruitment, and extremely slow growth rates. Height-frequency histograms for commercially harvested species remain truncated at the legal harvest size within the mussel refuge, suggesting illegal harvest. Zebra mussels (*Dreissena polymorpha*) have become well established in Reach 15 with mean densities of 2,519 ZBM/m^2 in July 1995 and unionid infestation at 48% by September 1995. Our data analysis and observations support the following management actions: (1) closing the commercial harvest of live *Megalonaias nervosa* in the UMR, (2) establishing entire reaches of the UMR as mussel refuges, (3) developing population models to guide and assist the management of mussels, and (4) monitoring zebra mussel densities and impacts in the Mississippi River.

14. SUBJECT TERMS

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The Long Term Resource Monitoring Program (LTRMP) for the Upper Mississippi River System was authorized under the Water Resources Development Act of 1986 as an element of the Environmental Management Program. The mission of the LTRMP is to provide river managers with information for maintaining the Upper Mississippi River System as a sustainable large river ecosystem given its multiple-use character. The LTRMP is a cooperative effort by the U.S. Geological Survey, the U.S. Army Corps of Engineers, and the States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin.